PUNA GEOTHERMAL VENTURE
A Hawaii Partnership

September 4, 1991

Dr. John Lewin, M.D.
State of Hawaii
Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

Subj: PERMIT TO OPERATE INJECTION WELL KS-3

Dear Dr. Lewin,

With reference to your letter relative to UIC dated March 16, 1990, Puna Geothermal Venture (PGV) hereby submits this application for a permit to operate well Kapoho State 3 (KS-3) under Underground Injection Control UIC Application No. UH-1529.

As stipulated in the above referenced letter, PGV is required to submit the following:

1) Geologic Report
2) Hydrologic Monitoring Program
3) Casing Monitoring Program

PGV submitted a Hydrologic Monitoring Program to the DOH in April of 1990. PGV is hereby submitting the geologic report and casing monitoring program to complete the documentation required for your review as necessary to receive a permit to operate.

If you have any questions please do not hesitate to contact me.

Sincerely,

Thomas G. Kizis

Thomas G. Kizis
Permit Coordinator

TK/cd

cc: D. Nakano, DLNR
E. Tanaka, DLNR
C. Hew, DOH
✓B. Anderson, DOH
N. Clark
M. Richard
B. Teplow
B. Rickard
File: 7.12 (KS-3), 7.12.3

(20929F/cd)

14-3860 Kapoho Pahoa Road, Pahoa, Hawaii 96778 • (808) 961-2786 • Facsimile (808) 935-5562
Post Office Box 1337, Hilo, Hawaii 96721-1337

ENGINEERING AND GEOLOGIC REPORT FOR INJECTION WELL KS-3

1. General Information
   a. Well Designation: Kapoho State 3
      Location: TMK 1-4-01:02, Kapoho, Puna, Hawaii (see Figure 1)
      Leased to: Kapoho Land Partnership
      Subleased to: Puna Geothermal Venture
      Operator: AMOR VIII Corporation

   b. Well Kapoho State 3, located on Pad E (see Figure 2), was the first geothermal well drilled by AMOR VIII to supply geothermal fluids to the Puna 1 Geothermal Power Plant. 5 other commercial wells have been completed or are under construction within the geothermal field (see figure 3). Elevation of the wellhead is 618 ft above sea level.

2. Physical Characteristics of the Area
   a. The Puna Geothermal Venture Project is a 500-acre lease located in the Puna District of the County of Hawaii, approximately 21 miles southeast of the city of Hilo, in the Kapoho Section of the Kilauea Lower East Rift Geothermal Resource subzone (see Figure 4).

   b. The project area lies on the windward side of the Big Island of Hawaii and receives 100 to 150 inches of rain per year. Day time winds are generally Trades blowing from the northeast, at 10 - 30 miles per hour, and night time winds blow from the northwest at slightly diminished speeds.

   c. The wellfield and power plant are located on the southern flank of Puu Honuaula, a cinder cone with a elevation of 860 ft. The topography to the south-southeast of the puu has a moderate slope of approximately 10° (15 ft./100 ft.). with some minor undulations. The wellfield to the southwest of the puu is generally flat with an average elevation of about 610 ft.

   d. Pad E was constructed on basalt flows from the 1955 eruption. The original surface was grubbed and a raised platform of compacted fill, consisting of rock and cinder, was constructed.

   e. Earthquake and volcanic hazard risks are high in the East

Rift Zone. Seismic and volcanic risk assessment reports were prepared for the project. Power plant structures conform with Seismic Zone 4 requirements and the brine injection pipelines were designed with expansion loops which will minimize the effects of fissuring, subsidence and ground swelling. The cellar of KS-3 was specially designed to be readily filled with volcanic cinders in order to reduce the chances of structural failure in the event of a lava flow.

f. Flood problems are not anticipated in the project area due to the highly porous nature of the surface basalt flows.

g. For information confirming conformance with local land use planning and zoning regulations, see Appendix I.

3. Description of System Operation

a. All geothermal fluids produced during operation of the PGV Project wellfield and power plant, including geothermal brine, geothermal steam condensate and geothermal noncondensible gases, will be injected back into the geothermal reservoir. Geothermal reservoir fluids will be produced typically from depths greater than 4,000 ft. and reinjected at equivalent depths.

The fluid from the production wells will be sent through a separator which will separate the steam from the residual brine. The brine will be directed to the injection facility and the steam will be directed towards the power plant. Within the environs of the power plant, the steam will pass through steam turbines and then low pressure OEC vaporizers. The by products of the power generation system are steam condensate and noncondensible gases. These three components, the separated brine, steam condensate and noncondensible gases, will be recombined prior to injection in order to produce a fluid with the same composition as the original geothermal fluid.

Table 1 shows the anticipated range of geothermal brine and steam condensate chemistries as described in the Puna Geothermal Venture GRP application. A representative analysis of the geothermal brines produced by KS-3 during the March 25-31, 1991 flow test, collected at wellhead pressures that best approximate power plant conditions, is displayed in Table 2. Table 2 also shows an analysis of steam condensate collected during the KS-3 flow test as well as water analyses from nearby PGV monitor wells and Puna District water supply wells (Pahoa and

Kapoho/Green Lake).

The anticipated range of noncondensible gas chemistries, modified from the PGV GRP application, is presented in Table 3. A representative gas analysis from KS-3, collected within minutes of the brine analysis in Table 2, has been added for comparison.

b. The 25 MW Net power plant is designed to run on 505,000 lbs/hr of steam derived from an original geothermal fluid that will separate into 80% steam: 20% brine. Anticipated volumes of injectate are as follows:

Condensate	505,816 lbs/hr
Brine	128,250 lbs/hr
Total NCG	1,183 lbs/hr
Total Flow	635,249 lbs/hr

c. The injection system (see Figure 5) consists of four components: one, a brine accumulator and brine injection pump; two, a noncondensible gas compressor, noncondensible gas system condensate pump and a noncondensible gas injection pump; three, a condensate accumulator, condensate pump, and condensate injection pump; and four, a water injection pump, necessary to maintain fluid volume if any OEC's are taken off-line. Each component of the system will be backed by spare fluid pumps. A spare noncondensible fluid compressor and a spare geothermal injection well will also be provided.

In the event of an upset in the injection system, the injectate will be discharged into an unlined holding pond at the power plant site constructed to receive and temporarily store the geothermal brine and/or condensate. Prior to discharge into the holding pond, the brine will pass through an emergency steam release facility.

The steam release facility will consist of two rock mufflers. Each rock muffler is designed to dissipate the steam's acoustic energy, thereby reducing the noise associated with steam release. Each muffler is designed to handle 570,000 lb/hr of steam, which is 100 % of the maximum total plant steam flow. Prior to entering the steam release facility, the steam will be treated with NaOH (caustic soda) and water to abate the majority of the H_2S entrained in the steam. Removal of 96 % of the H_2S is anticipated from the caustic treatment system

d. Two injection wells are planned to serve 8 production wells. To date only KS-3 has been completed (as a production well).

e. The maximum and average injection rates are equal, the anticipated operating volumes described in b.

f. The injection well will be utilized 24 hours per day.

g. No treatment of the steam or brine is planned under normal power plant operating conditions.

4. Geohydrologic Considerations

a. KS-3 is located on Pad E. Well head coordinates are 19° 28.69′ Latitude and 154° 53.67′ Longitude. Elevation is 618 ft. above sea level.

b. The lithology of KS-3 is summarized in Table 4. The formation consists wholly of tholeiitic basalts and differentiated tholeittic basalts deposited as extrusive flows which have been cross cut by differentiated tholeiitic intrusive dikes. The extrusive basalts can be subdivided into three units based on recognizable textural characteristics induced by their depositional environment. These units are subaerial aa and pahoehoe flows, submarine pillow basalts and a transitional unit consisting of hyaloclastites intercalated with subordinate volumes of pillow basalts and subaerial flows. The frequency of intrusive dikes increases with depth. Dikes are extremely rare in the upper 2,000 ft of KS-3 but are the dominant rock type below 6400 ft.

Qualitative evaluations of the subsurface permeability can be made from drilling data and down hole temperature surveys. Temperature surveys, see Figure 6, indicate that the upper 2000 ft. of KS-3 is extremely permeable and is filled with low temperature meteoric water. An impermeable layer between 2200 and 3000 ft. separates groundwater from geothermal waters. The interval between 3,000 and 3,900 ft. is impermeable with the exception of a moderate temperature (420 °F) geothermal fluid entry at approximately 3200 ft.

The casing shoe is set at 3,900 ft. and demarcates the open hole interval. The open formation can be divided into two segments. Between 3,900 ft. and 4,900 ft. the formation displays relatively low permeability; moderate to high permeability is encountered between 4,900 and

6800 ft. accompanied by measured fluid temperatures greater than 600 °F. Mud log records show permeable zones, reflected by high mud loss rates, between 6780 and 7200 ft. At the present time, there is a fish, consisting of approximately 511 ft. of drill assembly, left in the hole with the top of the fish at 6894 ft.

The formation encountered in the open section of the hole consists of two rocks types, pillow basalts and intrusive dikes. From drilling rates and examination of the core from SOH 1, the dikes are basically unaltered and non-fractured and behave as localized aquitards. The pillow basalts are brecciated with ample evidence for hydrofracing and fluid flow. Pillow breccias display varying degrees of hydrothermal alteration and vug mineralization.

The static water table was initially encountered at 645 ft. K.B. Measurements taken at a nearby monitoring well indicate that there is no tidal fluctuation of the depth to water level.

c. A water sample of the ground water was collected while drilling for analysis and the results are attached as Table 5. For comparison, chemical analyses of groundwater samples collected from the monitoring well MW-2, project water well, MW-1, and local water supply wells are included in Table 1.

d. An injection test was carried out using Hailliburton cement pumps on January 23, 1991 immediately after the well was completed. The test history is tabulated in Appendix II and plotted in Figure 7. Two pressure and temperature surveys were conducted during the test. Also a spinner was run with the pressure and temperature instruments. The pressure and temperature survey data is tabulated in Appendix III and plotted in Figures 8 and 9. The spinner surveys are plotted in Figure 10.

Pressure and temperature were monitored at 6800 feet for 8 hours after injection was shut off. The fall-off data is given in Appendix IV and plotted in Figure 11. The injectivity of the well based on the maximum pressure change measured during fall-off is about 1 gpm/psi (about 500 lbs/hr).

The pressure at 6800 ft. was decreasing during the injection test (refer to run #1 and run #2 on Figure 9), and correspondingly the injection capacity of the well was increasing. It is not clear what the ultimate injection capacity of the well would be. Using the injection rate and downhole pressure at the end of the injection test, the injection capacity for 200 oF water at an applied wellhead pressure of 150 psig is conservatively estimated at 550 gpm.

A Horner plot of the fall-off data is presented in Figure 12. The plot does not show a straight line portion from which a reliable analysis of formation properties can be made.

e. No other injection well has been completed by PGV.

f. The casing schematic and descriptions of materials are attached as figure 13. A fish, consisting of approximately 511 ft of drill collars, monel and drill bit, was left in the hole. The slotted production liner was run in to 6764 ft, a depth that is above the top of the fish.

William T Teplow — 9/9/91

William Teplow
Geologist — Date

WH Rickard — 9/9/91

William Rickard
Drilling Engineer — Date

PRODUCTION AND INJECTION WELL CASING MONITORING PROGRAM

1. INTRODUCTION

1.1 Background

Pursuant to Underground Injection Control (UIC) Permit No. UH-1529, the Hawaii State Department of Health (DOH) requires Puna Geothermal Venture (PGV) to develop a Casing Monitoring Program (CMP) regarding production and injection wells. This program is to be submitted to and approved by DOH prior to start of operation of injection wells drilled under permit UH-1529, for the PGV project site.

1.2 Purpose

The purpose of this CMP is to specify the observations, tests, drilling operations and, if necessary, remedial actions required to insure that the mechanical integrity of production and injection casing and cement is maintained throughout the drilling, testing and operation of PGV wells. The cemented and hung casing strings that are used in the PGV wells are designed to prevent contamination of any underground sources of drinking water (USDW) by either reservoir fluid in production wells or power plant effluent in injection wells. Contamination of the USDW's might occur if the casing strings are breached due to corrosion or mechanical failure or if there is a failure of the cement to seal the casing/borehole annulus above the zone of injection or production. The casing monitoring program described below is designed to detect and diagnose a loss of mechanical integrity in the casing or cement. Remedial actions required to restore mechanical integrity are also described.

1.3 Scope

This CMP covers all production and injection wells drilled by PGV and all existing wells that were drilled by previous operators on the 500 acre PGV site which to date have not been plugged and abandoned.

1.4 Hydrogeologic Basis for the Casing Monitoring Program

The hydrogeologic basis for the CMP is derived from data available from the drilling of five production wells to depths ranging from 6500′ to 8000′ and by two shallow monitoring wells drilled to depths of 640′ and 720′ (Figure 1).

1.4.1. The shallowest zone extending from surface (approximately 620′ above sea level) to about 7′ above mean sea level is unsaturated and consists of a highly permeable sequence of subareal basalt flows and interflow breccias. Within the project area this zone varies in thickness from 600′ to 720′ depending on the surface elevation. Numerous cracks with widths of up to 2′ traverse the area. These cracks are vertical or very steeply dipping and reach from the surface to at least the top of the warm unconfined aquifer described below. This is evidenced by the discharge of warm moist air from many of these cracks. The cracks trend parallel to the major structures and lineaments of the Lower East Rift Zone.

1.4.2 The zone below the unsaturated surface rock consists of an unconfined aquifer which contains ground water with varying degrees of natural contamination from the underlying geothermal system. This zone is approximately 1400′ thick with the water surface elevation controlled by sea level according to the Ghyben-Herzberg model. The unconfined aquifer surface in the project area is approximately 7′ above mean sea level. Based on the model, the thickness of the low salinity lens is therefore about 280′. This constitutes the USDW. The salinity of the underlying water will probably approach that of sea water. The temperature of the unconfined aquifer zone ranges from 95° to 192° F. in the project area and tends to be nearly isothermal throughout the entire interval, indicating good vertical mixing. A detailed description of this aquifer is given in the Puna Geothermal Venture Hydrologic Monitoring Program submitted to DOH in April 1990.

1.4.3. The interval from 1400′ below sea level to 2400′ below sea level (2000′ to 3000′ GL in Figure 2) is characterized by an extremely steep thermal gradient in the range of 30 F/100′ or more. The steep temperature gradient is characteristic of conductive heat transfer and indicates the zone has essentially zero vertical permeability. Thus, the zone appears to be an effective aquitard separating the high temperature geothermal fluid below from the low temperature unconfined aquifer overlying it. Locally the aquitard exhibits natural leakage as in the area of MW-2 and GTW-III where anomalously high shallow ground water temperatures and salinities are observed.

1.4.4 Between the depths 2400′ and 4300′ below sea level (3000′ to4900′ GL in Figure 2) the temperature profile indicates the existence of a transition zone which consists of alternating permeable and impermeable strata. Within this zone are two or more alternating zones of high thermal gradients and isothermal intervals. The high average thermal gradient through this zone indicates that vertical fluid circulation is very limited.

1.4.5 Below a depth of about 4300′ below sea level (4900′ GL in Figure 2) the temperature profile becomes nearly isothermal. This interval is within the geothermal reservoir in which significant vertical movement of fluid is taking place at temperatures above 620 degrees F.

The casing program planned for the production and injection wells calls for cemented casing to reach from ground surface to a depth of about 3400' below sea level (Figures 3 and 4). This allows the casing to be anchored securely within the transition zone described in 1.4.4 and to fully isolate the geothermal reservoir from the shallow aquifer (lowermost USDW) with a cemented interval through the aquitard (1400'-2400' below sea level). Within the shallow aquifer zone,two cemented casing strings are installed. Three cemented casing strings pass through the top of the shallow aquifer and the unsaturated zone. The production and injection casing programs are designed to prevent leakage of geothermal fluid from the wellbore into the shallow aquifer above a depth of 1400' below sea level. The CMP discussed below provides the methods and procedures necessary to detect any leakage and to repair those leaks if detected.

2. PRODUCTION WELL CASING MONITORING PROGRAM

2.1 Pressure Testing During Drilling

Each production well is completed with three casing strings (not including the 30-inch conductor pipe) cemented to the surface (Figure 3). Immediately upon completion of cementing each casing string and prior to drilling out the cement shoe, the casing will be pressure tested. The test will consist of pressurizing the casing to a specified test pressure and holding for 30 minutes. The specified test pressure shall be the lesser of: (a) 2000 psig surface pressure or (b) 70% of the casing internal yield pressure less 250 psi at the shoe. (2000 psig is the maximum expected surface pressure on the 9-5/8" casing during production operations.) The pressure drop during the 30 minute period shall not exceed 8%. The effect of the fluid expansion due to thermal recovery in the wellbore during the test period is expected to be negligible.

In the event that excessive bleed-off occurs, one or more of the following diagnostic methods will be used to locate the leak:

- Temperature log while injecting
- Shut-in temperature log
- Casing inspection logs with multi-arm caliper and/or magnetic inspection tools
- Pressure testing with a packer(s) on drillpipe
- Other applicable methods

After identification of the point of leakage, a cement squeeze job will be performed and the casing retested. Results of each pressure test will be reported to the Department of Land and Natural Resources (DLNR) and the Department of Health (DOH),

After a successful pressure test of each casing string, drilling will proceed to a point at least one foot below the cement shoe, and a pressure leak-off test will be performed to test the integrity of the annular cement. Each test will be performed at a pressure approaching the fracturing pressure of the exposed formation. If there is excessive leak-off, a squeeze cement job will be performed, the cement will be drilled out and the test will be repeated. Drilling will not proceed until an effective cement seal is established in the casing/borehole annulus above the shoe. In some situations, such as the case where there is natural formation permeability immediately below the casing shoe, it may not be practical to prove cement integrity with the pressure test described above. As an alternative, a standard water shutoff test (WSO) may be done above the shoe, or shut-in temperature surveys may be run.

If there have been indications of problems with the 9-5/8" cement job, a cement bond log (CBL) will be run in the 9-5/8" casing. Adequate cement curing time will be allowed before running the CBL.

Although CBL's may be of interest on the surface and intermediate casing strings, they are not planned because the necessary logging tools are not available from PGV's logging contractor to obtain meaningful results in the large diameter, 20" and 13-3/8" casing strings. CBL's are not commonly run in geothermal production and injection wells on the mainland, and they are virtually never run on the surface and intermediate casings. The large surface and intermediate casing sizes common to geothermal wells cannot be bond logged with useful results using conventional logging tools.

With regard to the surface and intermediate casing strings, if any problems are suspected from the results of the cement job or pressure testing, a shut-in temperature log will be run to check for interformational flows behind the casing. The shut-in time before logging will be sufficient to obtain useful results.

If the CBL is run in the 9-5/8" production casing it will be used only to determine cement tops or as a diagnostic tool. The logging results will not meet oil and gas standards for cement bond or cement compressive strength. This is due to two factors:

2.1.1 Because of the temperature limitations on logging tools, a well must be cooled by water injection during the logging operation. The resulting thermal contraction of the casing creates a temporary micro annulus between the casing and cement. Therefore, the log shows that no bond exists. This micro annulus is believed to seal after the well heats back up to the usual temperature. The micro annulus is usually so small that it would only be a problem with high pressure gas and would not provide a flow path for geothermal fluids.

2.1.2 The cement used in geothermal wells is relatively light weight, low compressive strength cement. Geothermal casing is usually cemented in place over its entire length and the cement used must be lightweight or the formation will fracture due to the hydrostatic pressure from the cement column. Fracturing and the resultant loss of circulation cause an incomplete primary cement job. Any secondary cementing procedure usually never approaches the quality of a successful primary cement job. All of the light weight cements available on the market produce relatively low compressive strengths when set. High compressive strengths are not required for geothermal wells because the casing is cemented over its entire length.

This supports and protects the casing and seals off any possible flow in the annulus. This is unlike the common practice in oil and gas wells where casing is cemented only to seal off the zones of interest or fresh water zones. The main method of determining the competency of the casing cement job while drilling will be the surface indications of pressure and circulation returns during the cement job and the shoe leak-off test. If both of these are positive, the cement job has an extremely high probability of providing a good seal against the migration of production fluids.

2.2 Monitoring During Injection Testing

Upon completion of each production well an injection test may be performed to give an initial indication of reservoir permeability. The injection test consists of pumping relatively cool, fresh water into the wellbore at several controlled rates while monitoring downhole and wellhead pressure. Temperature-pressure-spinner (TPS) logs will normally be run during the test. These logs can be used to locate leaks in the casing by noting a sudden change in temperature with depth or a drop in flow velocity within the casing string. In the event that a loss of mechanical integrity is indicated during or after injection, one or more of the following diagnostic methods will be used to confirm the leak:

- Temperature log while injecting
- Shut-in temperature logs
- Casing inspection logs with multi-arm caliper and/or magnetic inspection tools
- Other applicable methods as determined by PGV.

2.3 Monitoring During Flow Testing

During flow testing of each production well, wellhead temperature and pressure along with steam and brine flow rate and chemistry are continuously monitored. After the initial 24 hours of flow, flow characteristics tend to be stable. Sudden changes in the wellhead pressure, temperature, brine/steam ratio, or brine chemistry during stabilized flow can be indicative of a loss of mechanical integrity which is allowing cool water leakage into the wellbore.

Also during flow testing, TPS logs are periodically run. Leakage of cool water into the wellbore or loss of fluid to zones behind casing may be seen in the TPS logs run during or after shut-in. In the event that wellhead or logging data indicate a loss of mechanical integrity during the flow test, the well will be shut in and one or more of the following diagnostic methods will be used to confirm the leaks and locate it more precisely:

- Temperature log while injecting
- Shut-in temperature logs
- Casing inspection logs with multi-arm caliper and/or magnetic inspection tools
- Other applicable methods as determined by PGV

2.4 Monitoring During Production

Wellhead pressure and temperature will be monitored daily during normal production. Brine and steam chemistry will also be analyzed for each production well. Initially, samples will be taken weekly to establish a baseline geothermal fluid chemistry. The sampling frequency will then be reduced to monthly and quarterly as stabilization of the fluid chemistry is confirmed.

Casing failure causing leakage of cool ground water into the wellbore or loss of geothermal fluid to the formation may be manifested as a pressure and temperature drop at the wellhead. Fluid chemistry changes may also indicate ground water leakage. Wellhead pressure, temperature, and chemistry data will be reported to the DOH quarterly on a routine basis.

In the event that anomalous production parameters are observed, TPS survey(s) will be run with the well flowing. The TPS profiles will be used to determine whether the observed changes are due to changes in reservoir characteristics or are caused by a loss of mechanical integrity. In the event of a suspected loss of mechanical integrity, one or more of the following diagnostic methods will be used to confirm the leak and locate it more precisely:

- Temperature log while injecting
- Shut-in temperature logs
- Casing inspection logs with multi-arm caliper and/or magnetic inspection tools
- Other applicable methods as determined by PGV

2.5 Casing Repair

Once a loss of mechanical integrity is identified and approximately located, casing repair procedures will be initiated. These procedures may include any or all of the following activities:

2.5.1 Shut in well and run magnetic and multi-arm casing inspection logging tools to precisely locate leak and to evaluate casing condition.

2.5.2 Rig up workover rig on well. Run packer(s) on drillpipe and pressure test to confirm suspected leaking interval.

2.5.3 Execute cement squeeze job to seal casing leak or stop interformational flows behind casing.

2.5.4 Perform casing pressure test and other diagnostic tests as necessary to confirm success of the remedial work. If good, move rig off well and return well to production.

2.5.5 In the event of major casing failure, a cemented liner may be installed through the damaged interval.

2.5.6 Prior to drilling out the liner shoe, the liner will be pressure tested as described in Section 2.1.

2.5.7 If mechanical integrity cannot be restored satisfactorily, the well will be plugged and abandoned.

3. INJECTION WELL CASING MONITORING PROGRAM

3.1 Pressure Testing During Drilling

The cemented casing string design in PGV injection wells (Figure 4) is similar to that of production wells. Testing of each string will proceed as described in 2.1 above.

3.2 Monitoring During Injection Testing

Prior to installation of the hangdown liner, an injection test will be performed to measure injectivity of the open formation below the cemented 9-5/8" casing. During the test, one or more of the following logs or surveys will be run:

- TPS through the open hole and cased intervals with the well on injection.
- Shut-in temperature profile(s) to check for evidence of interformational flows behind casing.
- Other logs or surveys, as determined by PGV, to check for mechanical integrity of the casing and cement.

If the results of the logs and surveys confirm mechanical integrity, then the 7" hangdown liner will be installed. If leakage is found, repair procedures as described in 2.5 will be performed.

3.3 Monitoring During Routine Injection

During routine injection, the 7" x 9-5/8" annulus will be purged with nitrogen. Purge pressure and flow rate will be monitored for any changes indicative of a casing leak. Purge will be repeated as necessary to maintain the fluid level more than 1/2 way down the annulus. Once annually, tests and surveys will be conducted to verify mechanical integrity of the hangdown liner. The casing and hangdown liner will be tested for leaks by one of the following procedures, or a combination thereof:

3.3.1 Perform a pump-down test on the 7" x 9-5/8" annulus. Nitrogen will be injected into the annulus to a pressure sufficient to displace the water level to the 9-5/8" casing shoe and shut in. Surface pressure on the annulus and hangdown liner will be monitored and recorded. Annulus pressure bleed-off exceeding 8% in 30 minutes will be considered indicative of a leak. If necessary, the pressure test will be extended beyond 30 minutes to preclude thermal effects on the surface pressure. In that case, the final 30 minutes will constitute the test period.

<u>or</u>

3.3.2 If the hangdown liner is pulled, the casing may be pressure tested above a bridge plug or packer set near the shoe following the basic procedure outlined in Section 2.1. Integrity of the hangdown liner may be verified by inspection on the surface, by a pressure test after it is run in the hole, or by a TPS log with the well on injection.

Integrity of the cement will be checked during each workover by one or more of the following procedures:

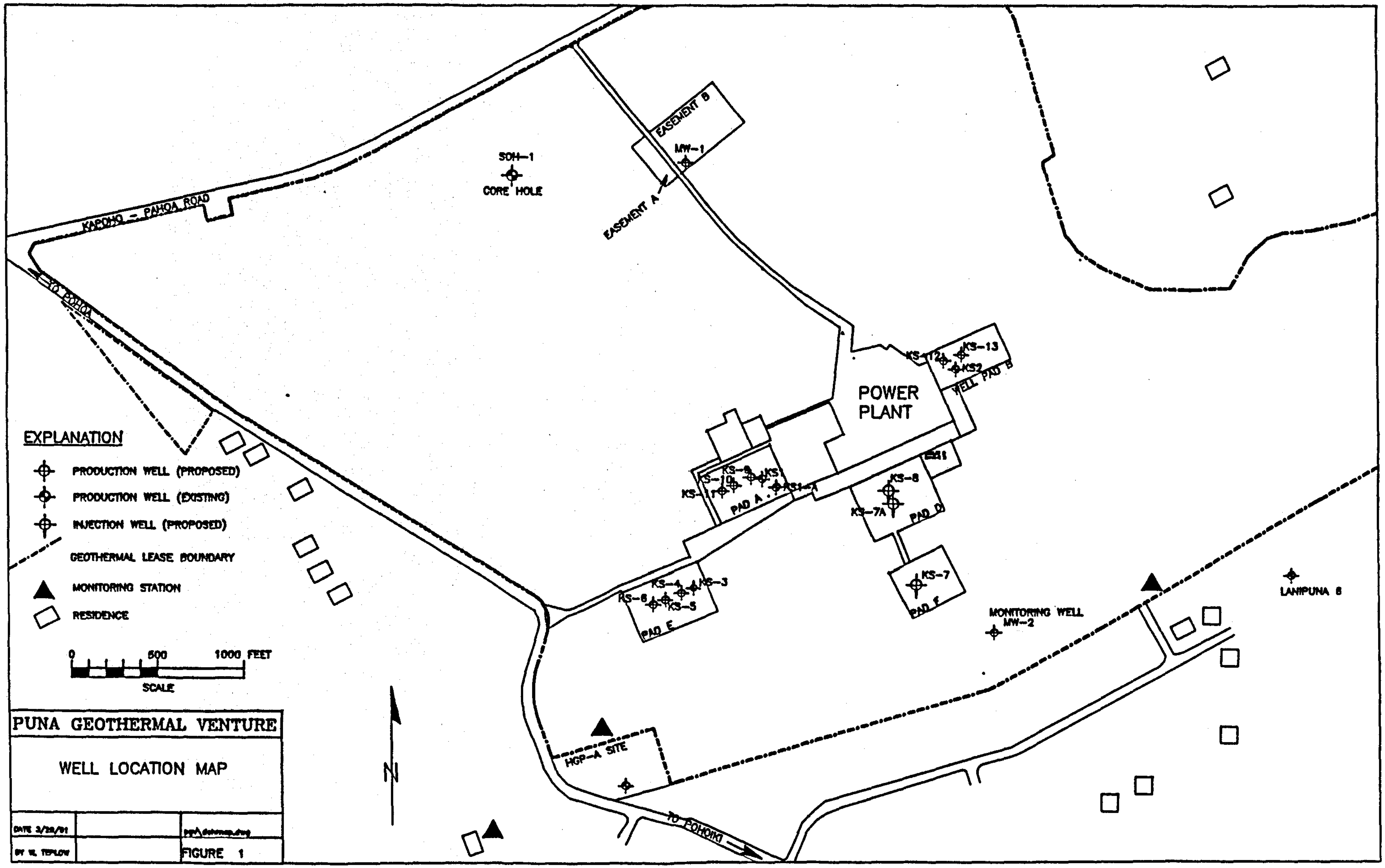
3.3.3 One or more shut-in temperature logs will be run. Shut-in time will be at least 12 hours, or longer if necessary to obtain meaningful results.

<u>or</u>

3.3.4 Other logs or surveys may be run, at the discretion of PGV, if shut-in temperature logs are not definitive.

3.4 Restoration of Mechanical Integrity or Abandonment

In the event that the diagnostic procedures indicate a loss of mechanical integrity, remedial or abandonment procedures will be carried out as specified in Section 2.5.



KAPOHO - PAHOA ROAD
TO PAHOA
SOH-1
CORE HOLE
EASEMENT B
MW-1
EASEMENT A
POWER PLANT
KS-12
KS-13
KS2
WELL PAD B
KS-8
KS-7A
PAD D
KS-7
PAD F
PAD A
KS-10
KS-11
KS-4
KS-3
KS-6
KS-5
PAD E
MONITORING WELL MW-2
LANIPUNA 6
HGP-A SITE
TO POHOIKI
N
EXPLANATION
PRODUCTION WELL (PROPOSED)
PRODUCTION WELL (EXISTING)
INJECTION WELL (PROPOSED)
GEOTHERMAL LEASE BOUNDARY
MONITORING STATION
RESIDENCE
0
500
1000 FEET
SCALE
PUNA GEOTHERMAL VENTURE
WELL LOCATION MAP
DATE 3/28/91
BY W. TEPLOW
FIGURE 1

PUNA GEOTHERMAL VENTURE
KS-3 STATIC AND FLOWING
TEMPERATURE PROFILES

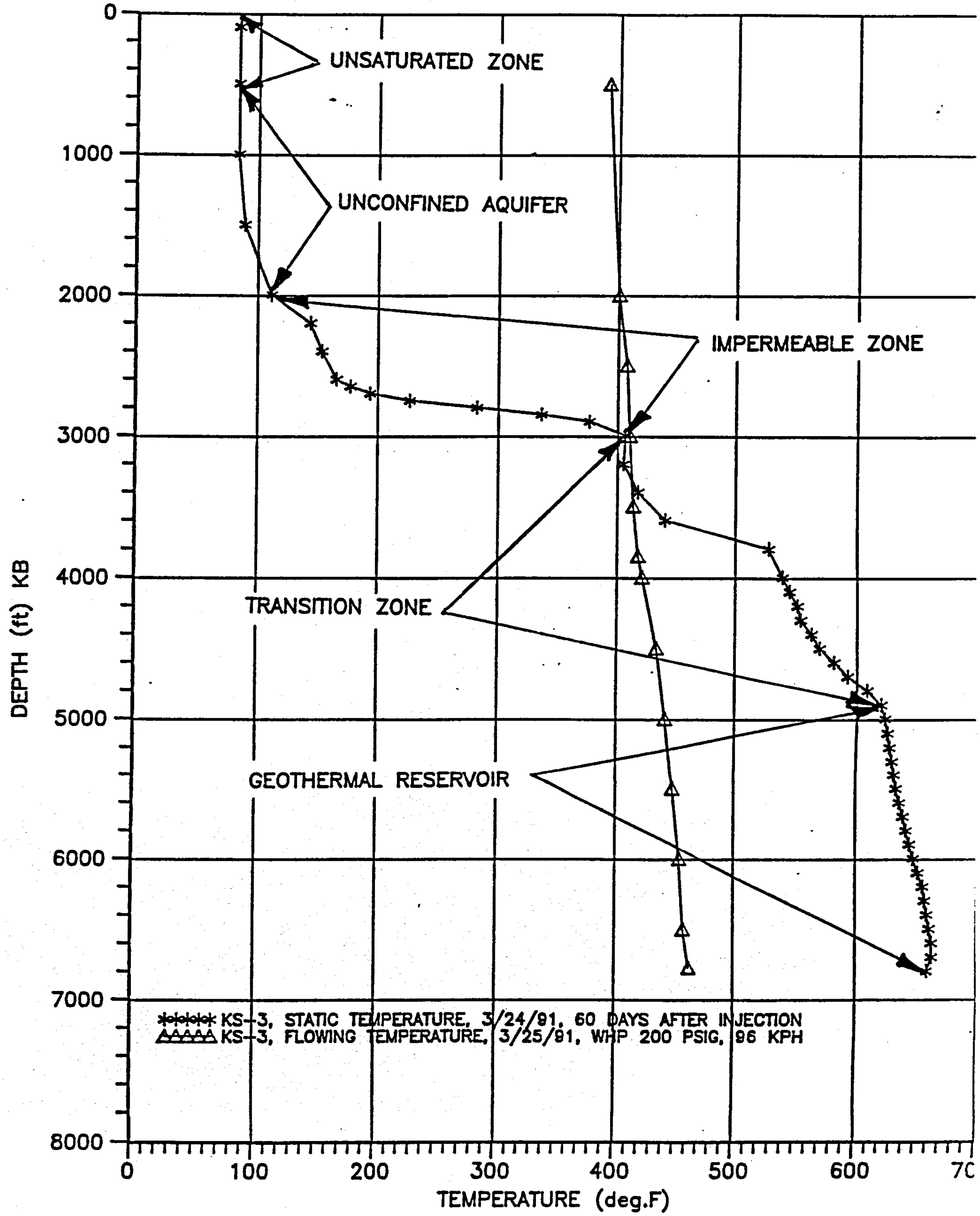
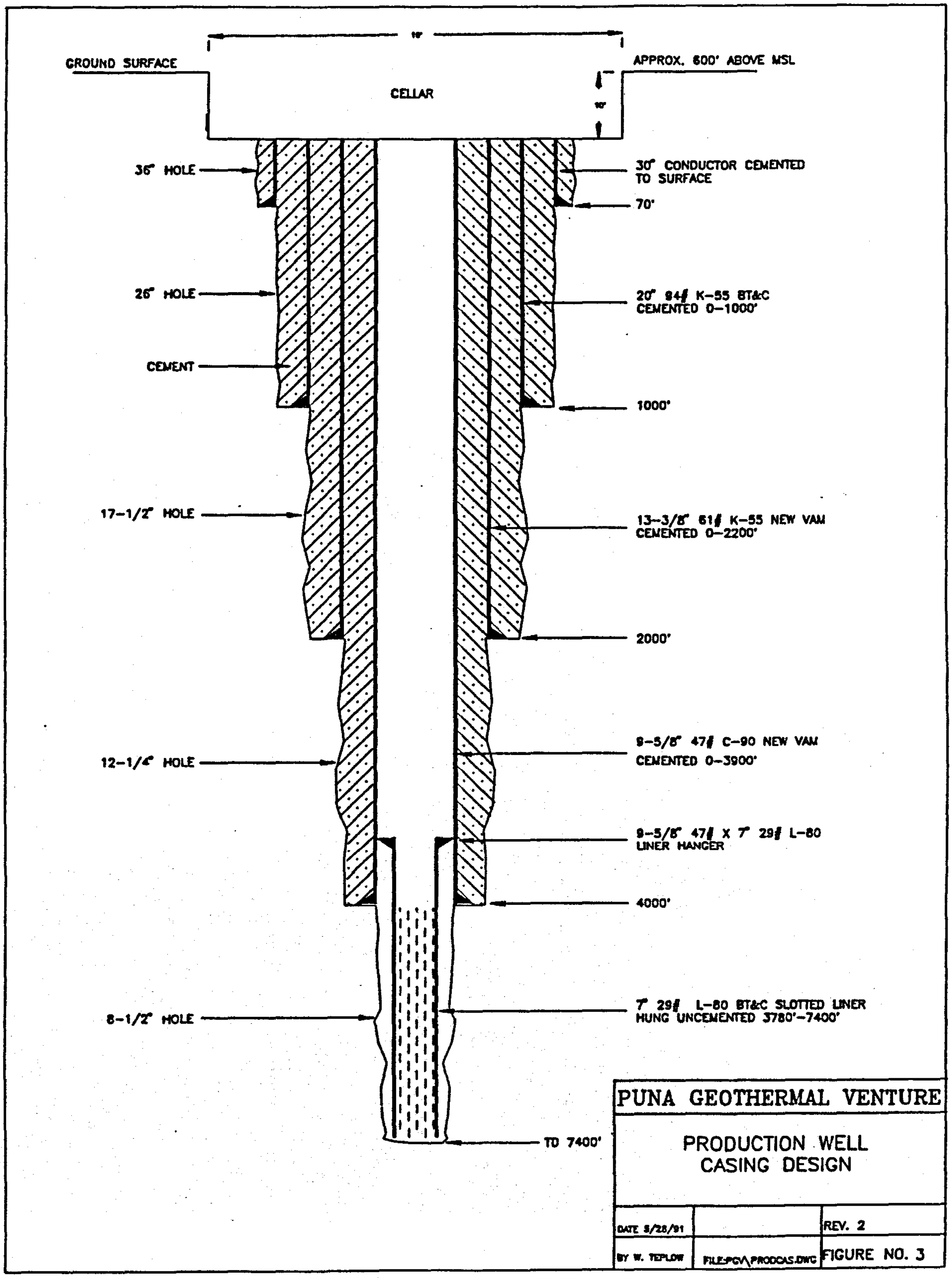
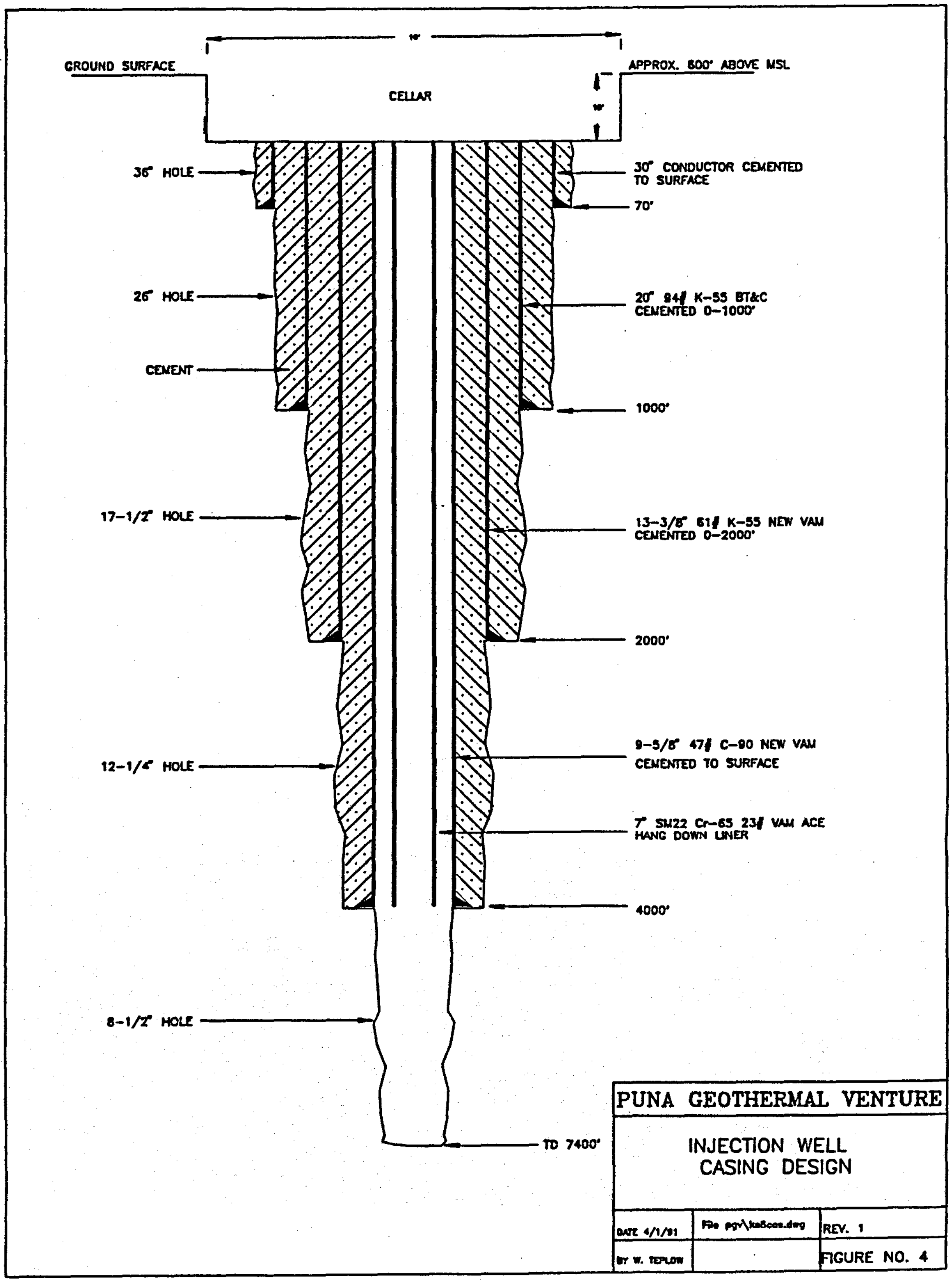


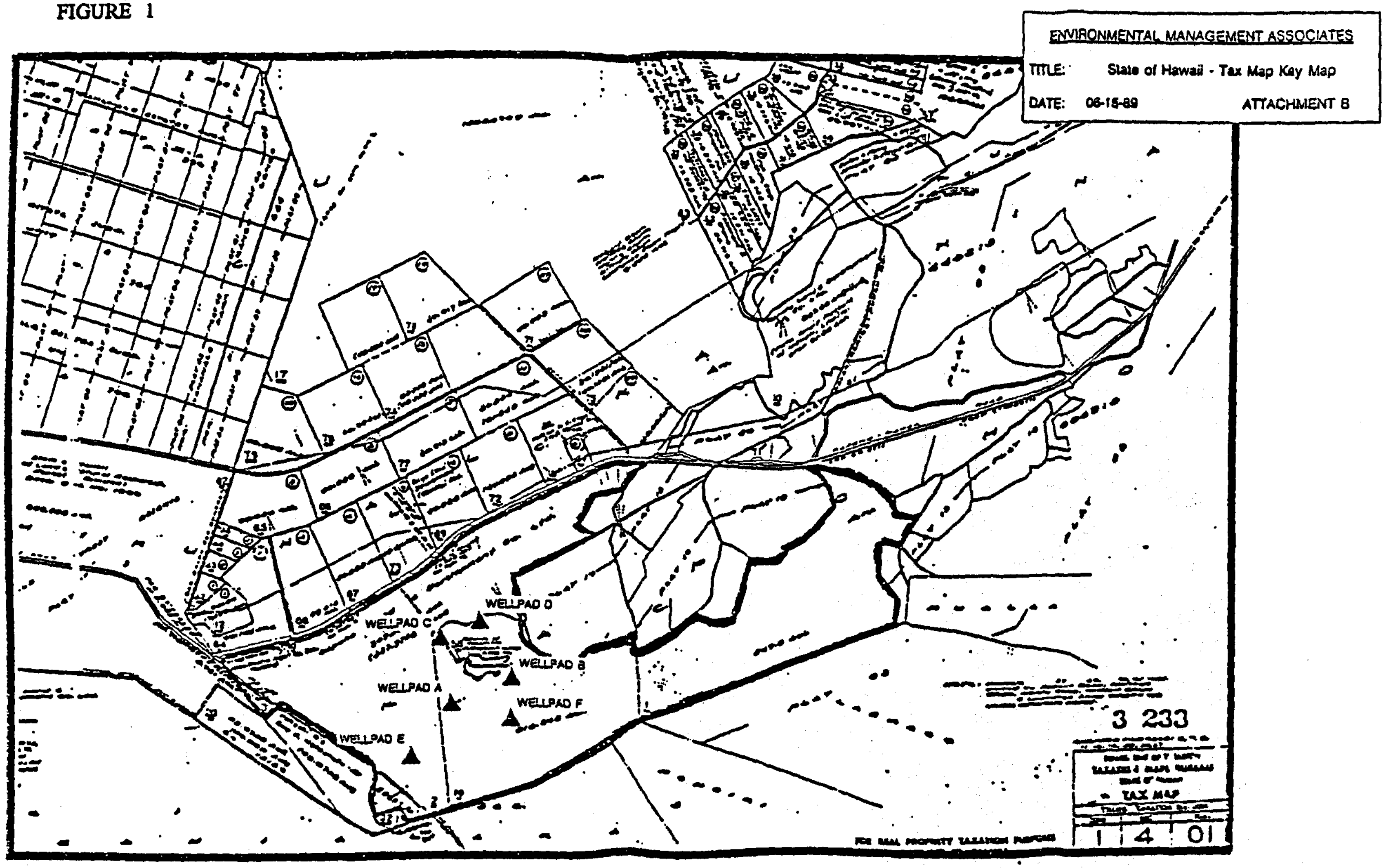
FIGURE 2


GROUND SURFACE
APPROX. 600' ABOVE MSL
CELLAR
36" HOLE
30" CONDUCTOR CEMENTED TO SURFACE
70'
26" HOLE
20" 94# K-55 BT&C CEMENTED 0-1000'
CEMENT
1000'
17-1/2" HOLE
13-3/8" 61# K-55 NEW VAM CEMENTED 0-2200'
2000'
9-5/8" 47# C-90 NEW VAM CEMENTED 0-3900'
12-1/4" HOLE
9-5/8" 47# X 7" 29# L-80 LINER HANGER
4000'
8-1/2" HOLE
7" 29# L-80 BT&C SLOTTED LINER HUNG UNCEMENTED 3780'-7400'
TD 7400'
PUNA GEOTHERMAL VENTURE
PRODUCTION WELL CASING DESIGN
DATE 5/28/91
REV. 2
BY W. TEPLOW
FILE:PGV\PRODCAS.DWG
FIGURE NO. 3



GROUND SURFACE
APPROX. 600' ABOVE MSL
CELLAR
36" HOLE
30" CONDUCTOR CEMENTED TO SURFACE
70'
26" HOLE
20" 94# K-55 BT&C CEMENTED 0-1000'
CEMENT
1000'
17-1/2" HOLE
13-3/8" 61# K-55 NEW VAM CEMENTED 0-2000'
2000'
9-5/8" 47# C-90 NEW VAM CEMENTED TO SURFACE
12-1/4" HOLE
7" SM22 Cr-65 23# VAM ACE HANG DOWN LINER
4000'
8-1/2" HOLE
TD 7400'
PUNA GEOTHERMAL VENTURE
INJECTION WELL CASING DESIGN
DATE 4/1/91
File pgv\ka6cas.dwg
REV. 1
BY W. TEPLOW
FIGURE NO. 4

FIGURE 1



ENVIRONMENTAL MANAGEMENT ASSOCIATES
TITLE: State of Hawaii - Tax Map Key Map
DATE: 06-15-89
ATTACHMENT B
WELLPAD D
WELLPAD C
WELLPAD B
WELLPAD A
WELLPAD F
WELLPAD E
3 233
TAX MAP
1 4 01

FIGURE 2

PROVED FOR
NSTRUCTION
TE: 7-10-90
VISION: -
: .n.

MASAHIRO NISHIDA
REGISTERED PROFESSIONAL ENGINEER
No. 4751 C
HAWAII, USA

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION.

9/6/9

Okahar
Associate
CONSULTING EN

200 KOHOLA STREET
HILO, HAWAII 96720
TEL: (808) 961-5527

470 N.
HON

PUNA GEOTHERMAL VENTURE
25 M.W. POWER PLANT
GRADING PLAN WELL PAD "E"

DRAWING NO.
8904

SHEET NO.
C-12

REVISION
^

FIGURE 3

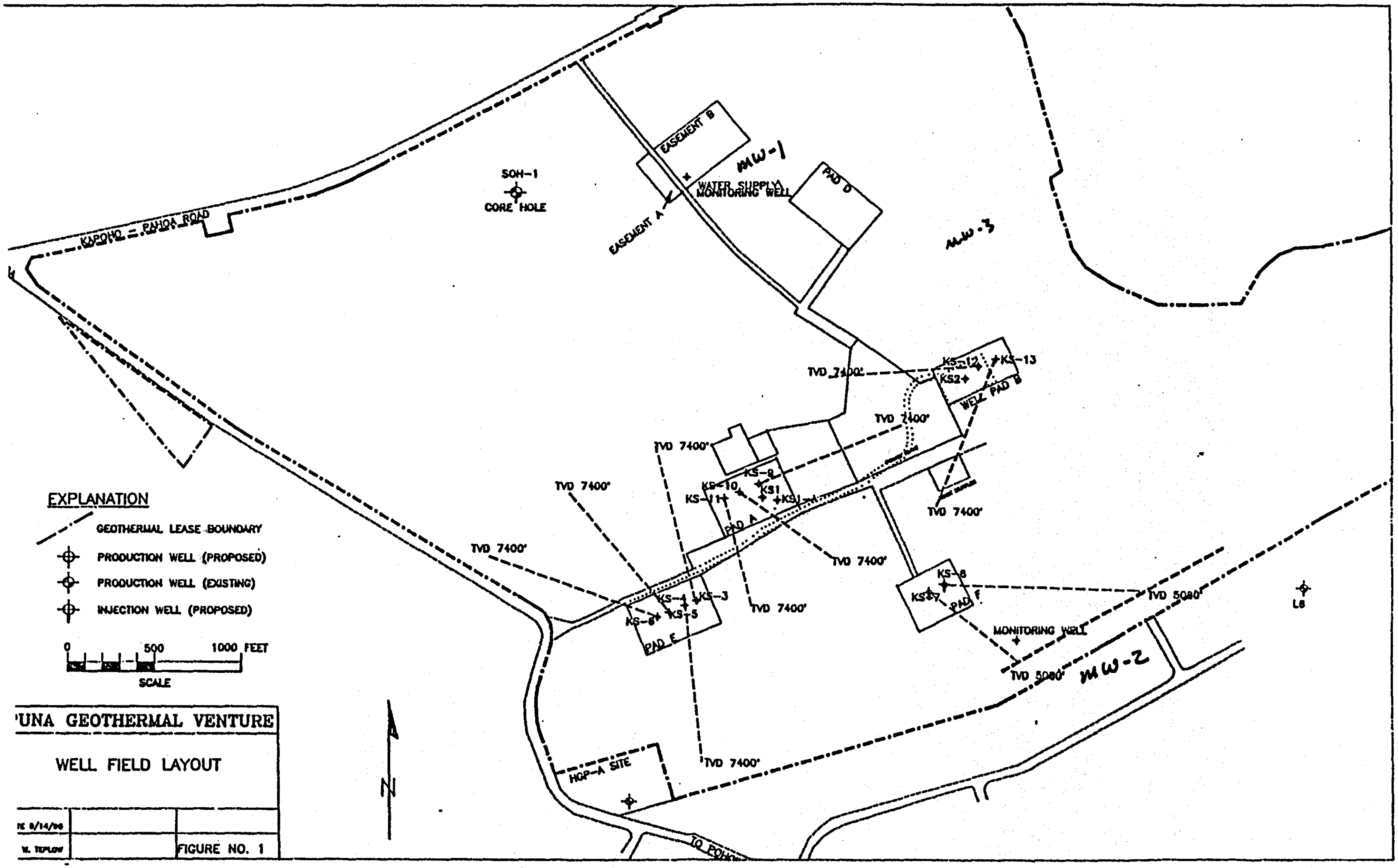
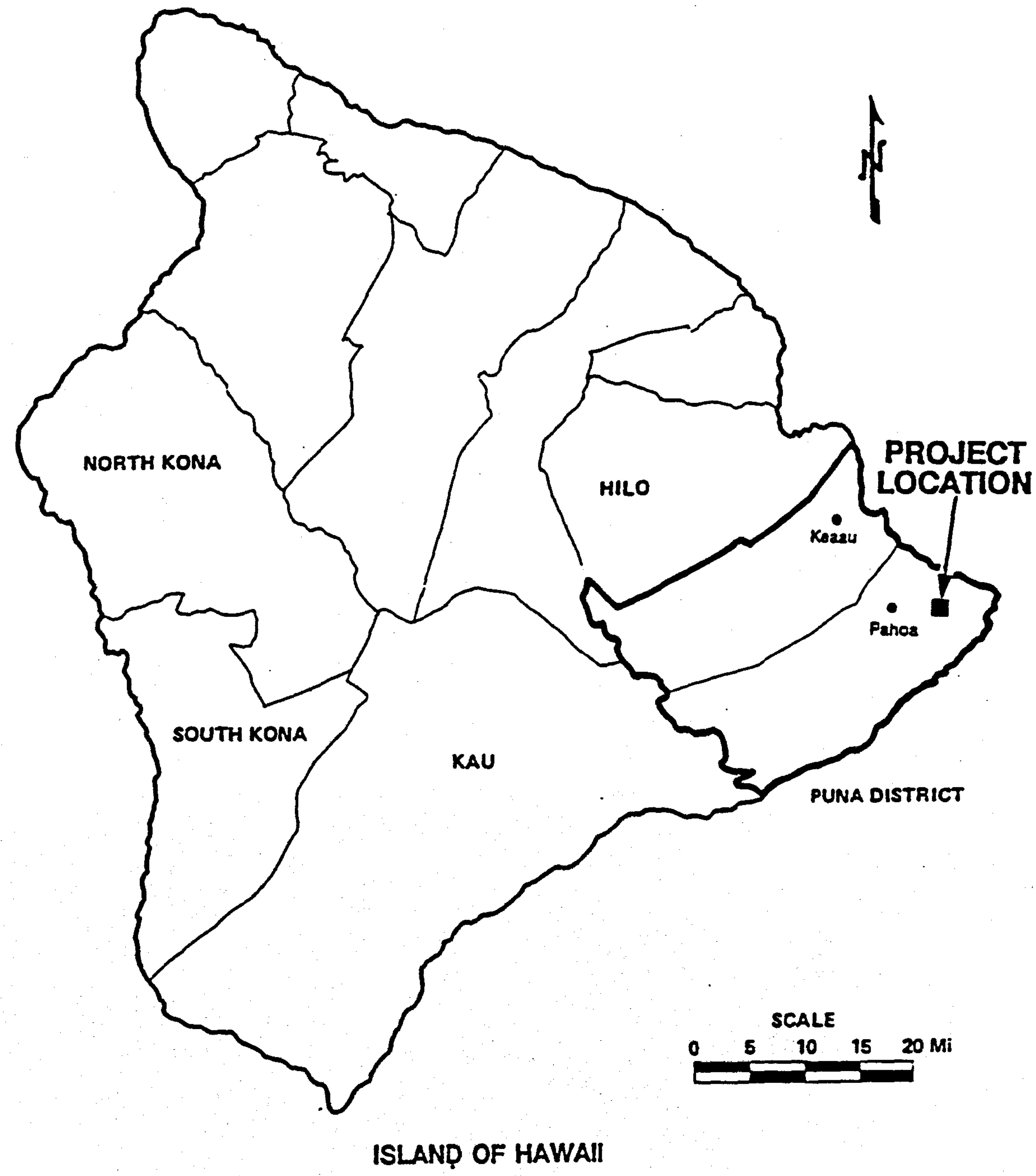

KAPOHO - PAHOA ROAD
SOH-1
CORE HOLE
EASEMENT B
EASEMENT A
MW-1
WATER SUPPLY
MONITORING WELL
PAD D
MW-3
TVD 7400'
KS-12
KS-13
KS2
WELL PAD B
KS-9
KS-10
KS1
KS-11
KS1-A
PAD A
KS-4
KS-3
KS-5
PAD E
KS-8
KS-7
PAD F
TVD 5080'
MONITORING WELL
MW-2
L6
HGP-A SITE
TO POHOIKI
EXPLANATION
GEOTHERMAL LEASE BOUNDARY
PRODUCTION WELL (PROPOSED)
PRODUCTION WELL (EXISTING)
INJECTION WELL (PROPOSED)
0
500
1000 FEET
SCALE
PUNA GEOTHERMAL VENTURE
WELL FIELD LAYOUT
FIGURE NO. 1
N

FIGURE 4



SOURCE: State of Hawaii, Department of Planning and Economic Development, STATISTICAL BOUNDARIES A-15. 1980:14

Figure 2-1. Location of the Puna District

FIGURE 5

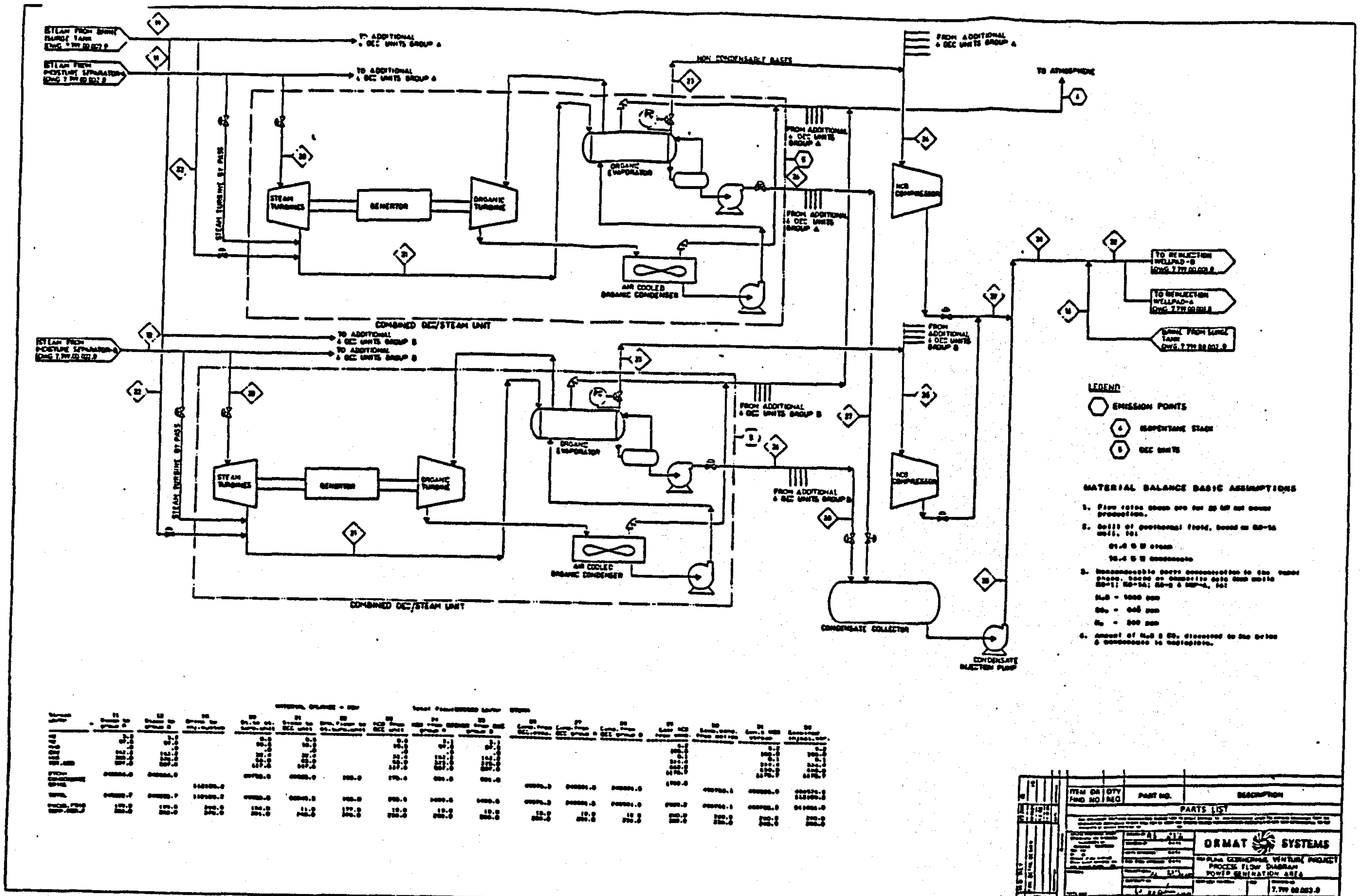


Figure 3-12

Figure 3-12. Power Generation Area Process Flow Diagram (Dwg. No. 7.799.00.003.0)

FIGURE 6

PUNA GEOTHERMAL VENTURE
KS-3 STATIC AND FLOWING
TEMPERATURE PROFILES

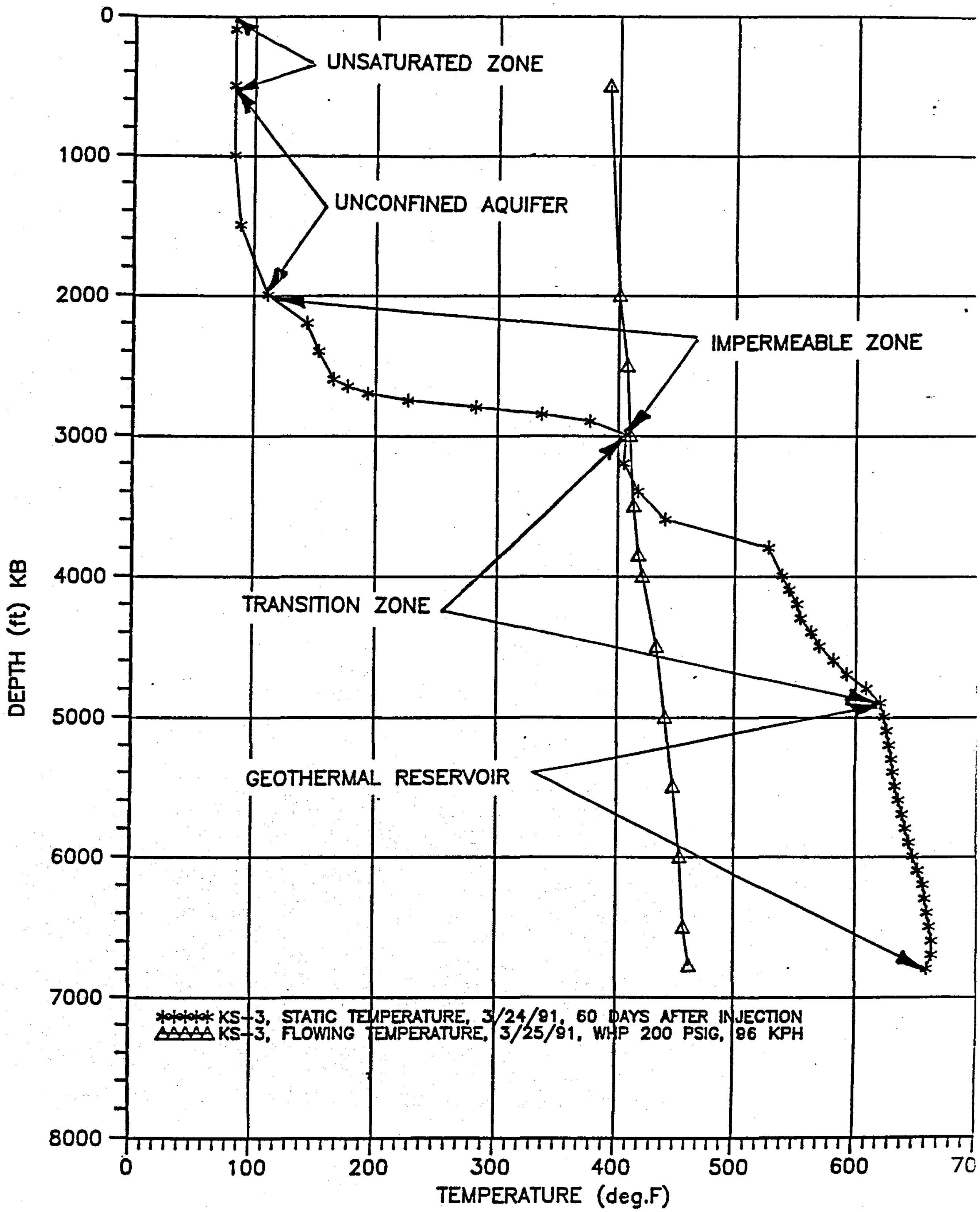
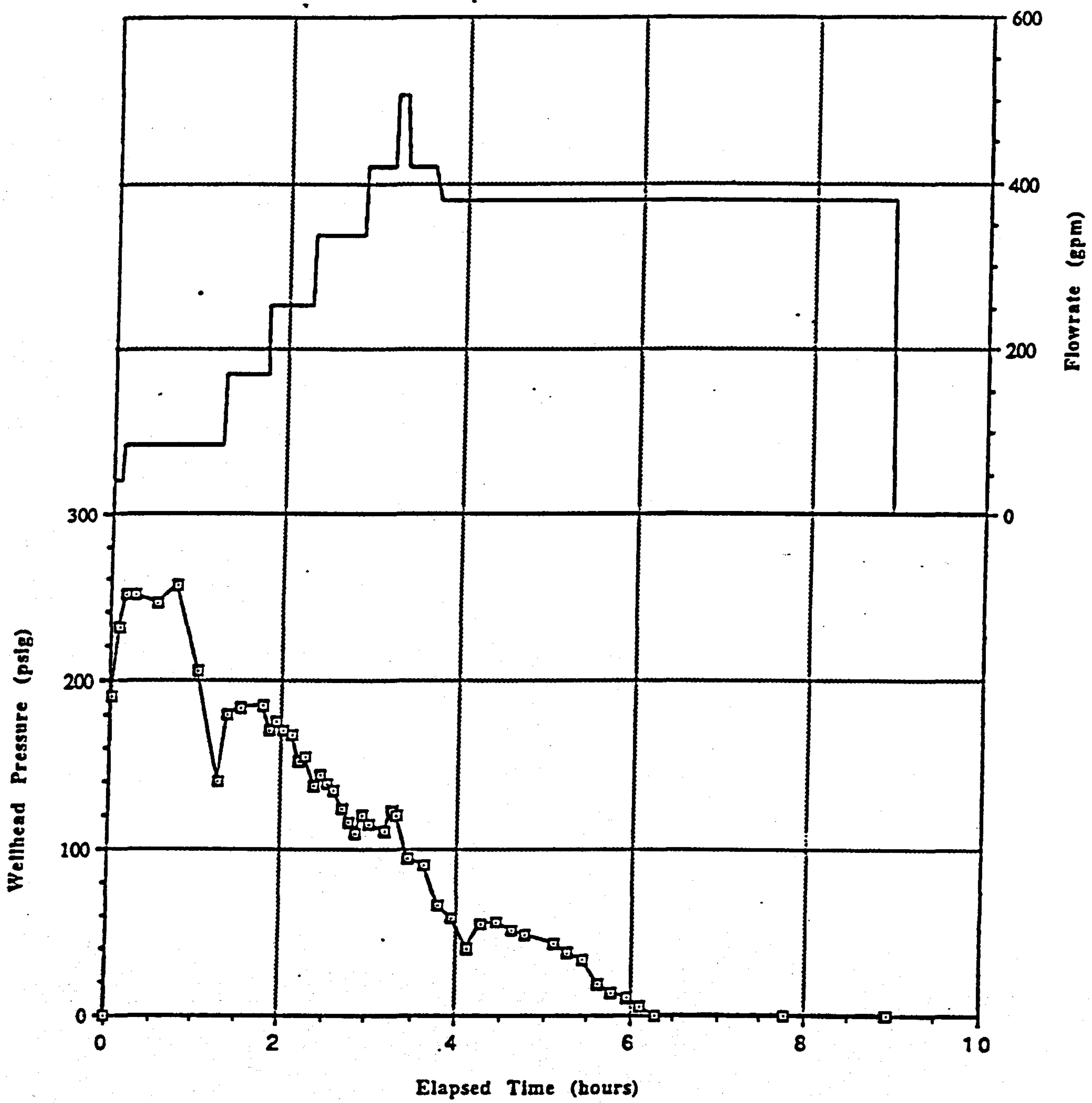


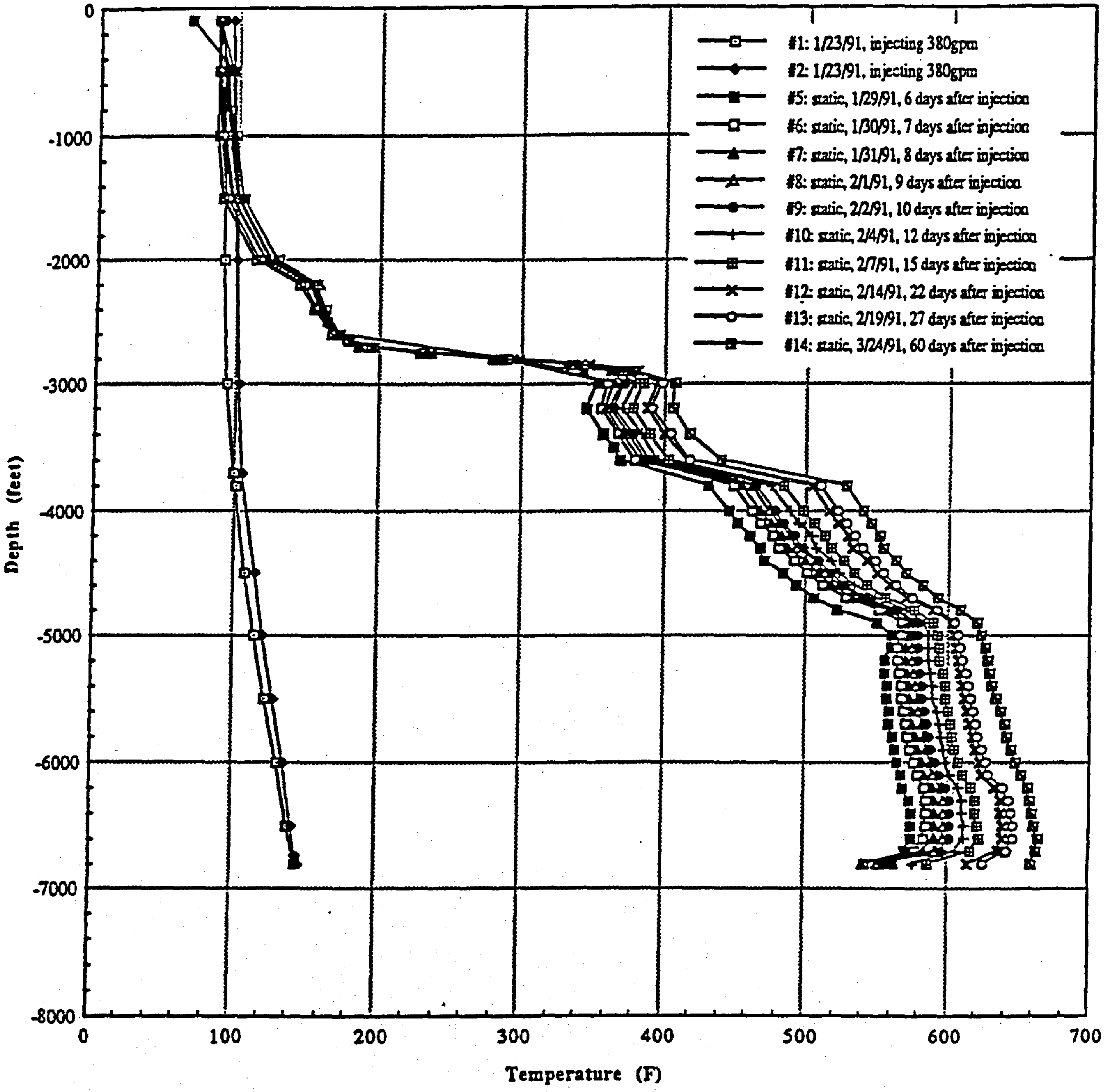
FIGURE 2

FIGURE 7



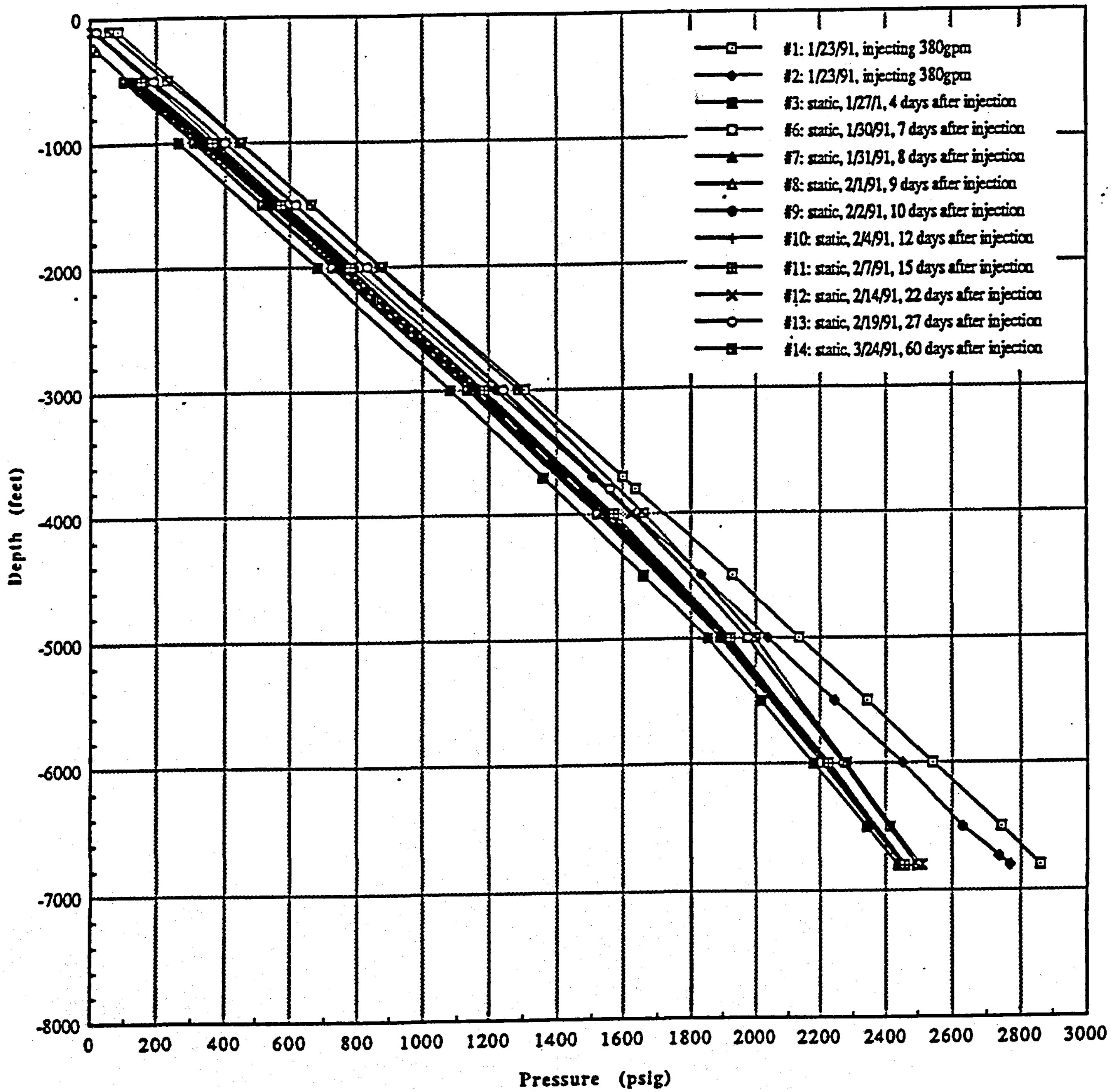
KS-3 Injection Test History, 1/23/91

FIGURE 8



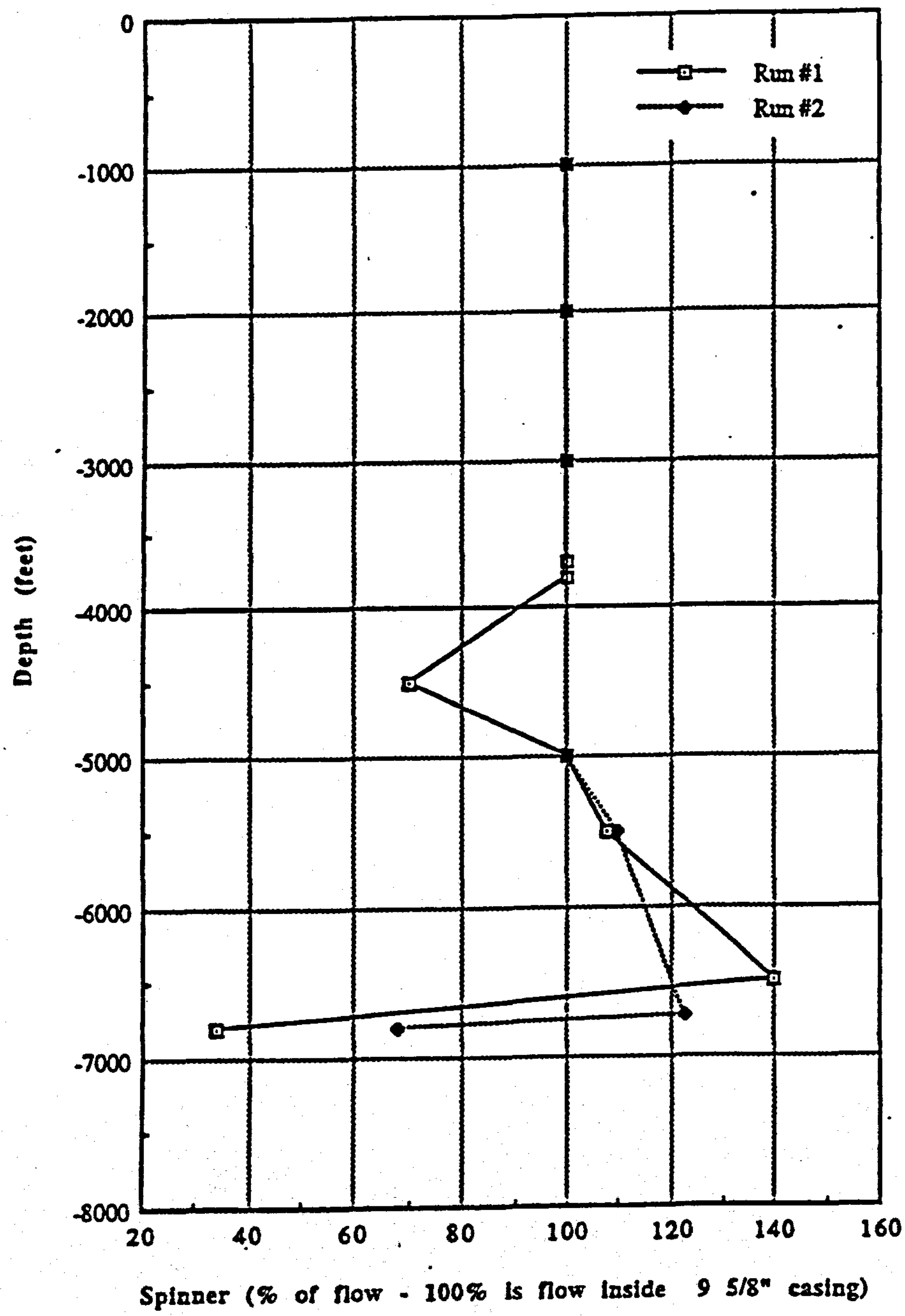
KS-3 Injection & Static Warm-up Temperatures

FIGURE 9



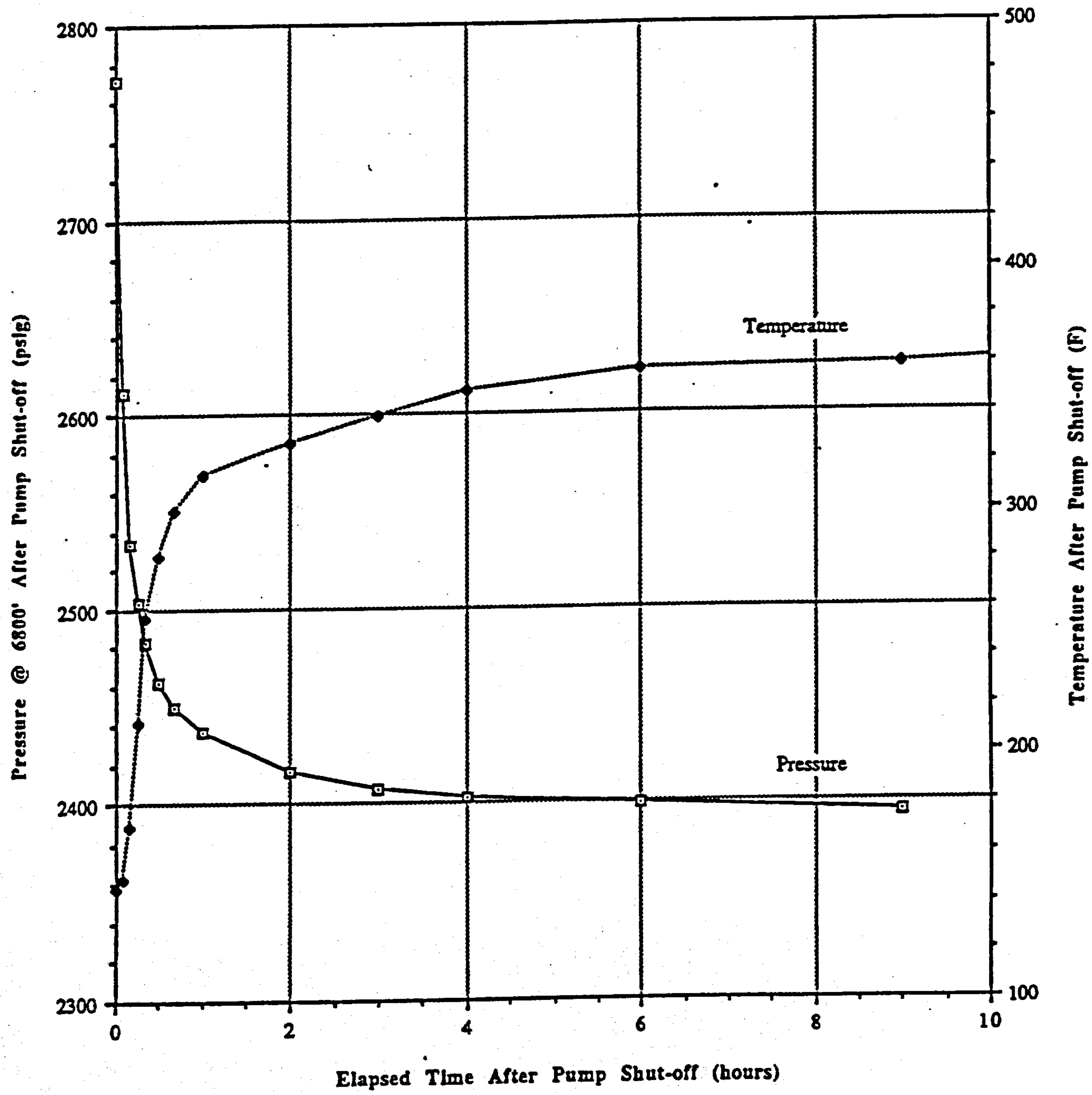
KS-3 Injection & Static Warm-up Pressures

FIGURE 10



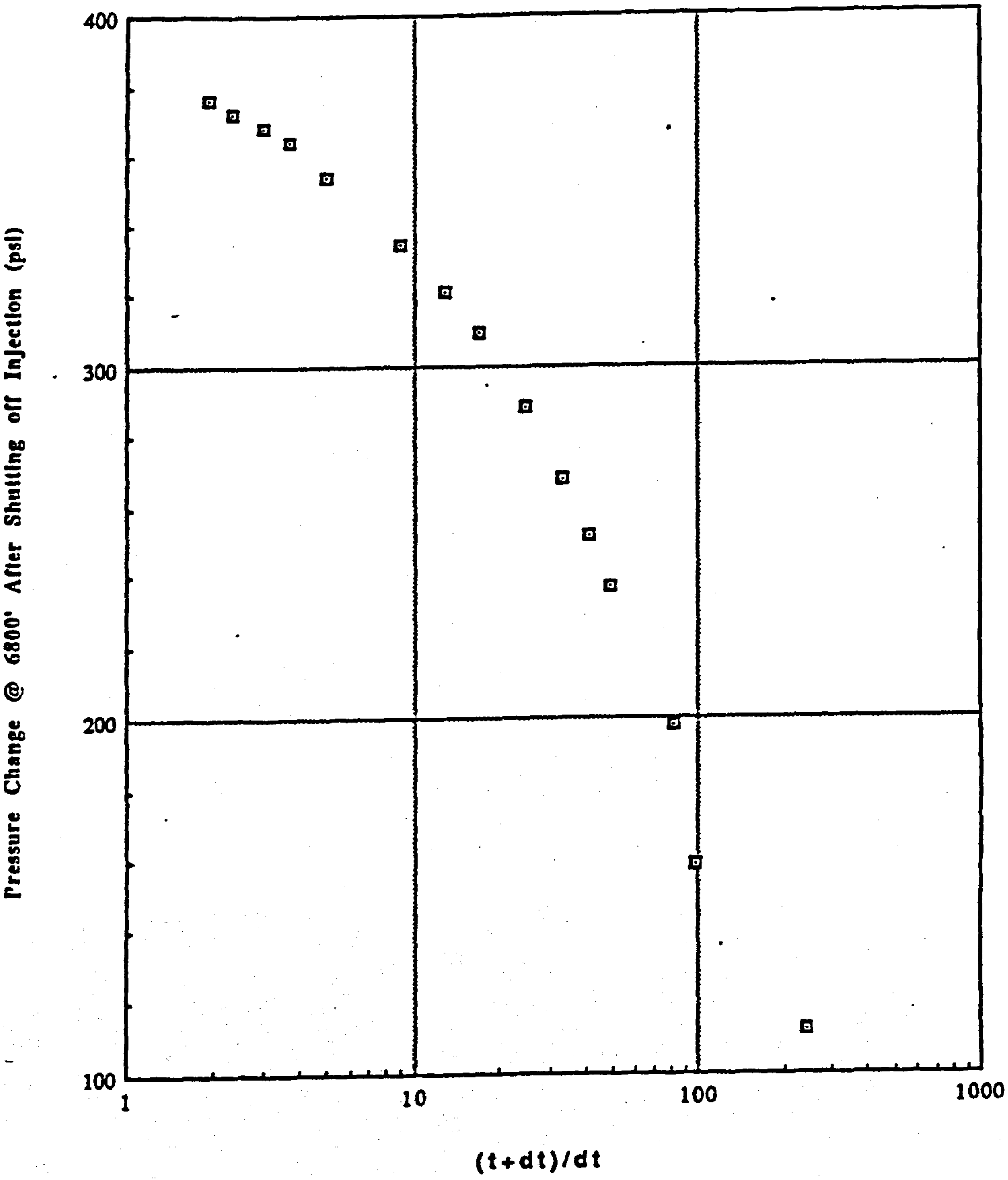
KS-3 Spinner while injecting water @ 380gpm

FIGURE 11



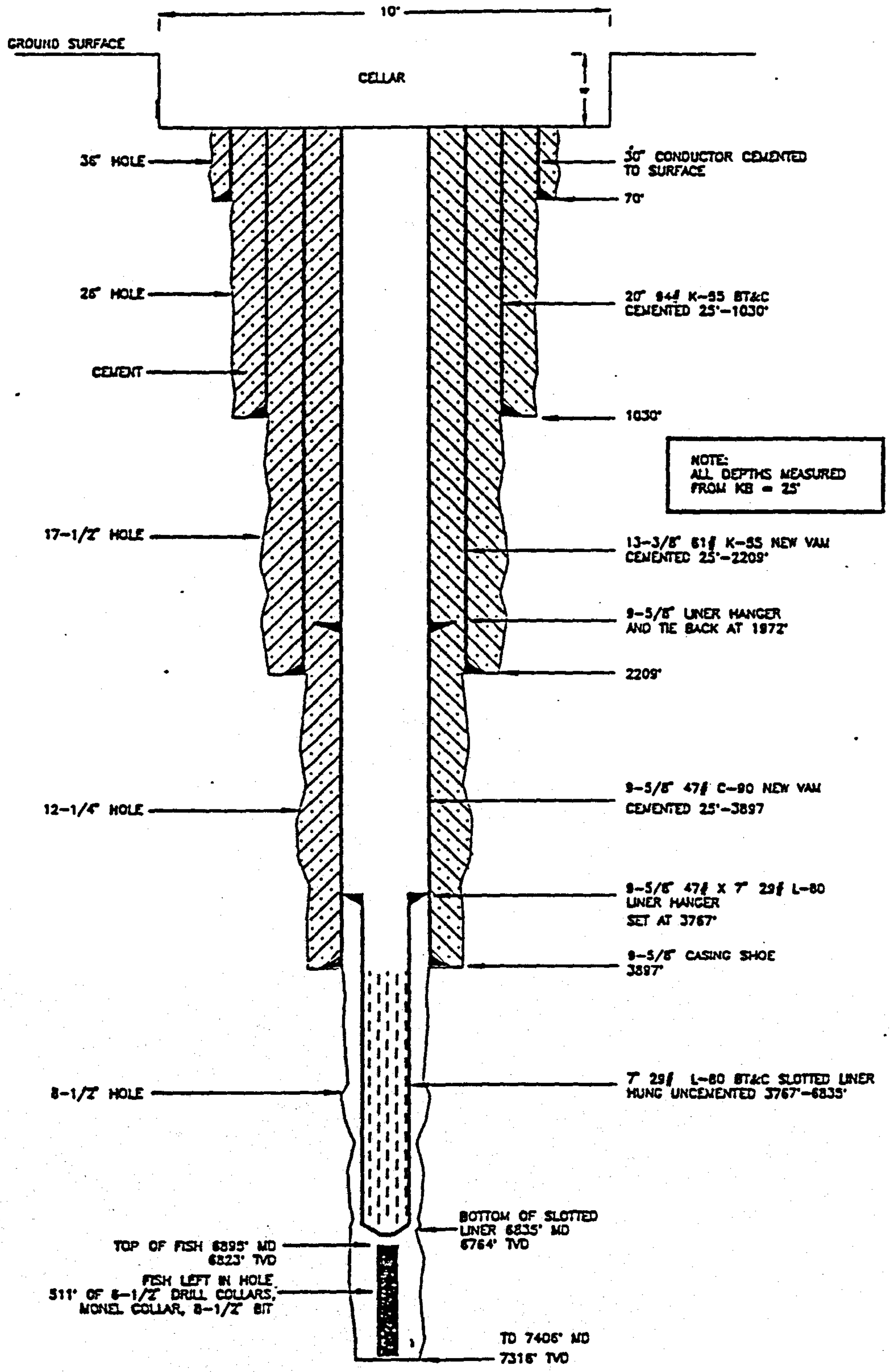
Pressure & Temperature Response @ 6800' After Injecting Water

FIGURE 12



Horner Plot of Injection Pressure Fall-off

FIGURE 13



PUNA GEOTHERMAL VENTURE		
KS-3 COMPLETION		
DATE 4/7/91		REV. 1
BY W. TEPLOW	FILE: PGV\KS3COMPL.DWG	FIGURE NO. 1

TABLE 1

PUNA GEOTHERMAL VENTURE
COMPARISON OF WATER CHEMISTRIES
KAPOHO STATE 3, PGV MONITOR WELLS
AND PUNA DISTRICT WATER SUPPLY WELLS

	Monitor Wells		Public Water Wells		KS-3		
Constituents (mg/l)	MW-1	MW-2	Pahoa	Kapoho	Brine	Steam Condensate	4,000 ft.
Arsenic	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND
Mercury	0.0002	0.0005	0.0004	0.0005	NA	NA	NA
Cadmium	ND	ND	ND	ND	ND	ND	ND
Lead	ND	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	ND	ND	ND	ND	ND
Barium	ND	ND	ND	ND	104.75	ND	6.39
Silver	ND	ND	ND	ND	ND	ND	ND
Lithium	0.05	0.08	ND	ND	16.28	ND	2.61
Boron	0.13	0.18	0.13	0.13	23.34	ND	5.07
Silica	102.00	9.10	55.80	58.30	1399.16	0.82	1044.30
Sodium	58.20	228.00	20.00	74.60	22674.93	27.34	2739.02
Vanadium	0.02	ND	0.04	0.11	ND	ND	ND
Nickel	ND	ND	ND	ND	ND	ND	ND
Bromide	ND	ND	ND	ND	ND	ND	ND
Nitrate	0.37	0.04	0.42	2.64	NA	NA	NA
Fluoride	0.31	1.18	0.29	0.23	2.00	0.09	0.93
Chloride	19.40	401.00	5.50	91.00	50100.00	7.80	5340.00
Calcium	19.20	24.00	3.02	34.10	3948.92	ND	280.11
Magnesium	12.50	12.00	2.76	20.60	58.32	ND	4.87
Potassium	10.60	19.00	2.70	7.03	5288.01	2.55	585.87
pH	7.67	7.68	7.79	7.67	3.58	6.35	4.74
T.D.S.	526.00	1036.00	195.00	580.00	85800.00	76.00	10250.00

ND: Not detected   NA: Not Available

Samples from MW-1, MW-2, Pahoa and Kapoho Wells collected March 19-20, 1991

Samples of Brine from KS-3 collected during Flow Test on March 31, 1991.
Wellhead pressure = 236 psig Wellhead temperature = 395 oF

Sample of Steam Condensate from KS-3 collected during Flow Test on March 30, 1991

Sample "4,000 ft" collected at 4,000 ft. M.D. using a downhole sampling tool on April 18, 1991.

TABLE 2

Puna Geothermal Venture Project
Geothermal Resource Permit Application Amendment

Composite Geothermal Fluid Chemical Composition

Element	Brine[a] (ppmw)			Steam Condensate[a] (ppmw)
Na	600	-	10,000	0.17
K	123	-	2,700	0.1
Ca	40	-	920	0.1
Mg	1	-	2	<0.1
Fe	<1	-	8.4	0.05
Mn	<1	-	8.5	-
B	4	-	11	<0.5
Br	40	-	80	-
I	<20			-
F	0.2	-	0.9	-
Li	1	-	9	<0.01
Cl	925	-	21,000	<2
NH	<0.01	-	0.10	0.12
SO_3[b]	9.2	-	24	13
Hg	<0.001	-	<0.05	-
As	0.09	-	0.4	<0.01
S[c]	5	-	100	-
Total Alkalinity	≤10			<10
HCO_3	0	-	18	0
CO_3	0			0
SiO_2	420	-	1,500	0.7
TSS	70			-
TDS[d]	2,500	-	35,000	15
pH	≤5	-	5.5	3.5
Conductivity (mhos/cm)	3,100	-	67,000	120
Density	1.03			-

Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well.

[a]Wellhead pressure = 155 psig;
Wellhead temperature = 368°F
[b]Concentration high due to oxidation of $S^=$ to SO_4
[c]Concentration low due to oxidation of $S^=$ to SO_4
[d]TDS = Total Dissolved Solids

TABLE 3

PUNA GEOTHERMAL VENTURE NONCONDENSABLE GAS COMPOSITIONS: COMPARISON OF KAPOHO STATE 3 AND OTHER PUNA GEOTHERMAL WELLS

Constituent (ppmw)	KS-3 3/31/91	Composite Wells	Power Plant Design Composition
Carbon Dioxide	487.00	250 – 1,042	600
Hydrogen Sulfide	654.00	800 – 1,300	1300
Ammonia	0.17	–	–
Argon	0.30	6 – 13	–
Nitrogen	13.10	10 – 700	50
Methane	1.55	–	–
Helium	–	<0.009	–
Hydrogen	13.20	11 – 1,412	20
Total NCG	1170.00	1500 – 2200	1970

Composite Wells:	KS-1, KS-1A, KS-2 and HGP-A Wellhead pressure = 155 psig Wellhead temperature = 368 oF
KS-3:	Wellhead pressure = 236 psig Wellhead temperature = 395 oF
Power Plant:	Backpressure = 10 psig Temperature = 230 oF

TABLE 4

KAPOHO STATE 3 GEOLOGY SUMMARY

MEASURED DEPTH (K.B.)	LITHOLOGY
Surface to 1150 ft.	No sample; Drilled with no returns
1150 to 3050 ft.	Subbaerial Basalts: Intercalated lava flows, cindery basalts, scoria zones and weathered interfaces. Two types of basalts occur as vesicular and non-vesicular flows: 1. Olivine-Tholeiitic basalt: rare to trace, locally common, phenocrysts of olivine and subordinate plagioclase in an aphanitic to glassy groundmass. 2. Differentiated Tholeiitic basalts: porphyritic with common to abundant phenocrysts of olivine, plagioclase and pyroxene in a fine-grained holocrystalline to hyalocrystalline groundmass composed of microlites of plagioclase, pyroxene and magnetite. Includes a small percentage of intrusive dikes.
3050 to 4040 ft.	Transitional Zone: Hyaloclastites (layered units composed of granular fragments of volcanic glass, locally conglomeritic, derived from basaltic ash eruptions, littoral deposits and black sand deposits) intercalated with differentiated basalts and less commonly tholeiitic basalts. Differentiated basalts represent intrusive dikes or surface flows. Tholeiitic basalts probably deposited as submarine pillow basalts or surface flows.
4040 to 6450 ft.	Submarine Basalts: Tholeiitic pillow basalts, glassy, aphanitic basalt with rare to trace, locally common, phenocrysts of olivine and plagioclase, intercalated with minor units of hyaloclastite. Section is cross-cut by microporphryritic to porpyritic intrusive dikes composed of differentiated basalt, phenocrysts of plagioclase, olivine and pyroxene in a holocrystalline groundmass of plagioclase, pyroxene and magnetite. Coarse-grained diabasic unit of differentiated basalt encountered between 4700 and 4740 ft.
6450 to 7406 ft.	Intrusive Dike Complex: Microporphyritic to porpyritic differentiated basalts as above with subordinate thin intervals of pillow basalts and hyaloclastite deposits.

BREWER ENVIRONMENTAL SERVICES
a Department of Brewer Environmental Industries
P.O. BOX 552 PAPAIKOU, HAWAII 96781 PHONE: 964-5522 FAX: 964-5309

TABLE 5

JOB NO. 2711
DATE DEC. 04, 1990
PAGE 1 OF 2

LABORATORY ANALYSIS REPORT (1)

TO: PUNA GEOTHERMAL VENTURE ATTN:
ADDRESS: P.O. BOX 1337 PHONE:
HILO, HAWAII 96721
SAMPLES OF: WATER
SAMPLED BY: CLIENT SAMPLING DATE: 11/20/90 TIME: 1415
RECEIPT DATE: 11/21/90 TIME: 1150

DATE SAMPLE ANALYZED			11/28/90			
TIME SAMPLE ANALYZED						
SAMPLE TYPE						
SAMPLE DESCRIPTION	UNITS		KS3-1 WELL WATER #1			
METALS:						
ARESENIC	mg/L		<0.002			
BARIUM	mg/L		<0.1			
CADMIUM	mg/L		0.01			
CHROMIUM	mg/L		0.05			
LEAD	mg/L		0.06			
MERCURY	mg/L		0.0011			
SELENIUM	mg/L		<0.002			
SILVER	mg/L		<0.01			
CALCIUM	mg/L		10.8			
MAGNESIUM	mg/L		3.6			
NICKEL	mg/L		0.06			
POTASSIUM	mg/L		3.3			
SODIUM	mg/L		33.4			
VANADIUM	mg/L		0.7			
LITHIUM	mg/L		0.01			
BORON	mg/L		2.8			
SILICA	mg/L		41.8			

LABORATORY REMARKS: Samples analyzed according to "Methods for Chemical Analysis of Water and Wastes", U.S. Environmental Protection Agency, March, 1979 and/or "Microbiological Methods for Monitoring the Environment", U.S. Environmental Protection Agency, August, 1978.

Douglas Root

ANALYTICAL LABORATORIES
of Brewer Chemical Corporation
PAPAIKOU, HAWAII 96781 PHONE: 964-5522

JOB NO. 2711
DATE DEC. 04, 1990

ORATORY ANALYSIS REPORT (2)

: PUNA GEOTHERMAL VENTURE ATTN:
ODDRESS: P.O. BOX 1337 PHONE:
HILO, HAWAII 96721
SAMPLES OF: WATER
SAMPLED BY: CLIENT SAMPLING DATE: 11/20/90 TIME: 1415
RECEIPT DATE: 11/21/90 TIME: 1150

DATE SAMPLE ANALYZED			11/28-12/03/90			
TIME SAMPLE ANALYZED						
SAMPLE TYPE						
SAMPLE DESCRIPTION	UNITS		WELL WATER #1			DETECTIO LIMITS
ENDRIN	mg/L		ND			0.0002
LINDANE	mg/L		ND			0.0002
METHOXYCHLOR	mg/L		ND			0.0010
TOXAPHENE	mg/L		ND			0.005
2,4-D	mg/L		ND			0.005
2,4,5-TP (Silvex)	mg/L		ND			0.001
NITRATE	mg/L		1.39			
FLUORIDE	mg/L		0.41			
CHLORIDE	mg/L		7			
TOTAL DISSOLVED SOLIDS	mg/L		388			

LABORATORY REMARKS: Samples analyzed according to "Test Methods for the Evaluation of Solid Waste Physical/Chemic Methods", SW-846, U.S. EPA Office of Solid Waste, Washington, DC 20460.

ND = NOT DETECTED

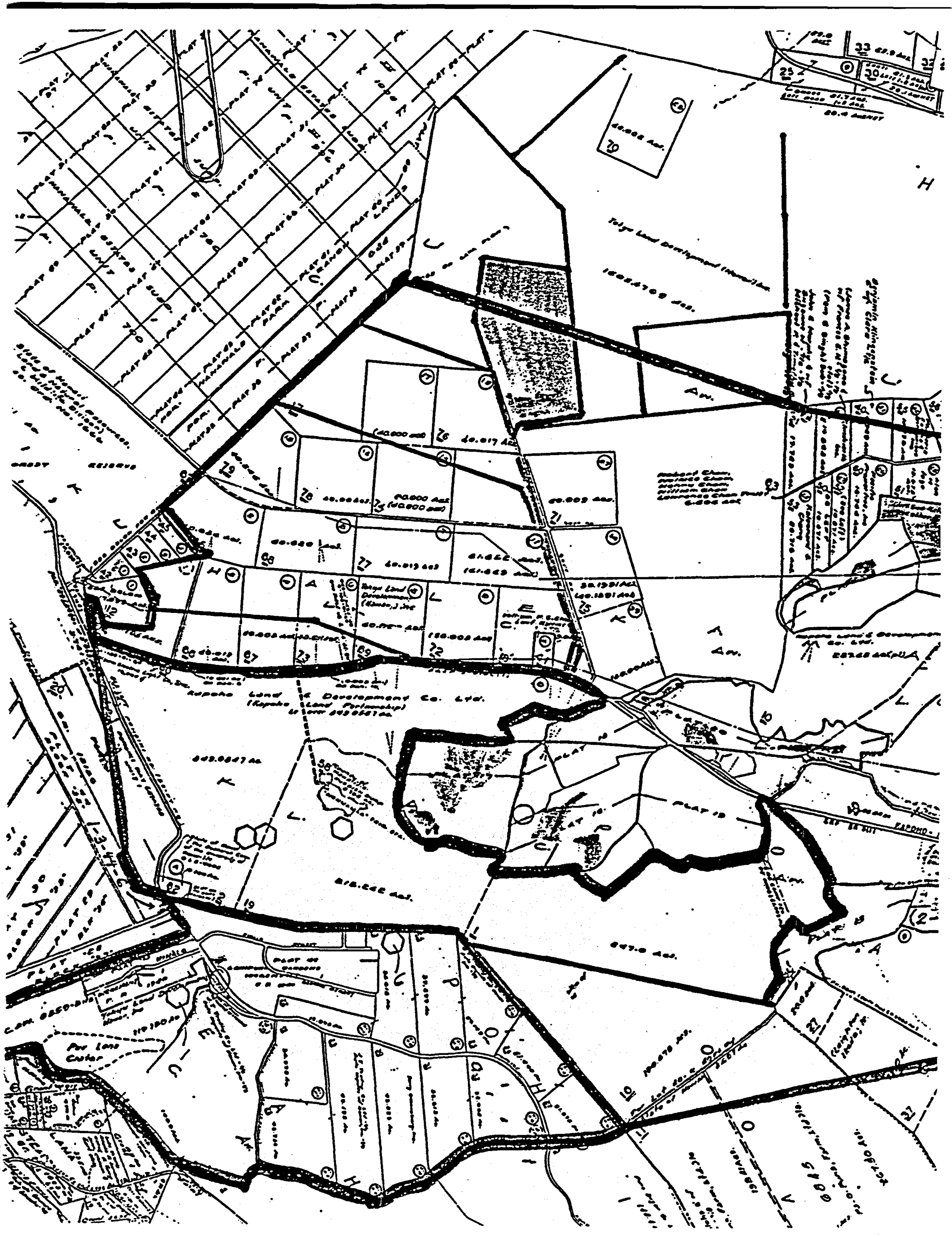
APPENDIX I

GEOTHERMAL RESOURCE SUBZONE
(KAPOHO SECTION)

TAX MAP KEY	AREA (ACRES)	LAND USE CLASSIF.	LAND OWNERS	
✓1-4-01-10(POR.)	258.69	AG/3ac	KAPOHO LAND AND DEV. CO. LTD.	
1-4-01-13	3.21	AG/3ac	KAPOHO LAND AND DEV. CO. LTD.	
			KAPOHO PROPERTIES INC. etal	
1-4-01-21(POR.)	15.95	AG/3ac	MURPHY, JOHN E. etal	
1-4-01-26(POR.)	1.01	AG/3ac	REID, RANDOLPH K./LAURIE B.	
1-4-01-27(POR.)	2.41	AG/3ac	REID, RANDOLPH K. etal	
			WALKER, VIVIAN	
1-4-01-28(POR.)	0.69	AG/3ac	IMAINO, PAUL M.	
1-4-01-31(POR.)	5.44	AG/3ac	SHINDE, YOSHIO/HELENE TRS.	
1-4-01-32(POR.)	5.35	AG/3ac	SHINDE, YOSHIO/HELENE TRS.	
1-4-01-33(POR.)	17.51	AG/3ac	KLINGENSTEIN, CLARA L.	
			R.C. ROBERTS AND CO.	
			KENNY, DUANE	
1-4-01-40(POR.)	8.47	AG/3ac	KLINGENSTEIN, CLARA L.	
1-4-01-41	5.00	AG/3ac	CHOW, WILLIAM PC/HARRIET L.	
1-4-01-46(POR.)	3.54	AG/3ac	MEACHUM, DOUGLAS F./JUDY	
1-4-01-50	10.87	AG/3ac	MARTIN, CARY L.	
1-4-01-51	13.67	AG/3ac	YOZA, ALLAN M.	
1-4-01-52	10.87	AG/3ac	MARTIN, BETTY L.	
1-4-01-53	20.71	AG/3ac	CHANG, KALEONANI S.	
			COLEMAN, KALEONANI	
1-4-01-54(POR.)	13.00	AG/3ac	SHIMOZONO, JAMES A. etal	
1-4-01-55(POR.)	9.39	AG/3ac	PLUMERIA FARMS AND ENT. INC.	
1-4-01-56(POR.)	3.58	AG/3ac	YAMADA, RYUICHI/ A., etal	
			TEASDALE, RAYMOND	
1-4-01-59	26.06	AG/3ac	PERRY, DELAN A./JENNIFER V.	
1-4-01-60	18.74	AG/3ac	HANSHAW, FREDERICK J.	
1-4-01-63(POR.)	3.00	AG/3ac	CHOW, ROBERT etal TR.	
1-4-01-64	585.76	AG/1ac	KAPOHO PROPERTIES INC. etal/BARNWELL IND. INC.	
1-4-01-65	142.54	AG/1ac	INDEX INC. etal	
1-4-01-66(POR.)	73.46	AG/1ac	INDEX INC. etal/ VIKING PROPERTIES INC.	
1-4-01-67(POR.)	64.28	AG/1ac	KAPOHO PROPERTIES INC. etal/BETTENCOURT GEORGE C/E A	
1-4-01-68(POR.)	32.14	AG/1ac	PUNA SUGAR CO. LTD.	
1-4-01-69(POR.)	26.73	AG/1ac	KAPOHO PROPERTIES INC. etal/VIKING PROPERTIES INC.	
1-4-01-70	414.25	AG/3ac	KAPOHO PROPERTIES INC. etal/BARNWELL IND. INC.	
1-4-01-72	0.61	AG	KAPOHO PROPERTIES INC. etal	
1-4-01-81(POR.)	1.17	AG/3ac	REID, RANDOLPH K./ LAURIE B.	
1-4-02-2	1089.30	CONS-L	KAPOHO LAND AND DEV. CO. LTD.	
1-4-02-10	180.47	AG/10ac	DAIICHI SEIKO OF HAWAII INC.	
1-4-02-11	2.69	AG/10ac	STATE OF HAWAII	
✓1-4-02-18	454.89	SPLIT	KAPOHO LAND AND DEV. CO. LTD.	SPLIT:AG/123.52;CONS-L/331.37
1-4-02-27	20.00	AG/10ac	BISHOP B.P. TR. EST.	
			HANOHANO, EPHRAIM K./FELISA	
✓1-4-02-31	303.87	SPLIT	KAPOHO LAND AND DEV. CO. LTD.	SPLIT:AG/256.29;CONS-L/47.58
✓1-4-02-32	444.50	SPLIT	KAPOHO LAND AND DEV. CO. LTD.	SPLIT:AG/357.50;CONS-L/87.00
1-4-02-34(POR.)	323.56	AG/10ac	RICHFIELD OF HAWAII INC. etaL	
1-4-02-37(POR.)	36.00	AG/10ac	BISHOP B.P. TR. EST.	
			IKEDA, LEIGHTON	
✓1-4-02-40	48.44	AG/3ac	KAPOHO LAND AND DEV. CO. LTD.	
1-4-02-41	10.08	AG/10ac	KAPOHO LAND AND DEV. CO. LTD.	

CONTINUED ON NEXT PAGE

PRELIMINARY
SUBJECT TO ...



Time Clock hrs	Elapsed Time hrs	Wellhead Pressure (psig)	Injection Flowrate (gpm)	Event/Comment
13:13	0.00			Start Injection
13:15	0.03	190	42	
13:19	0.10	230	42	
13:20	0.12		84	Increase Injection Rate
13:23	0.17	250	84	
13:30	0.28	250	84	
13:45	0.53	245	84	
14:00	0.78	255	84	
14:15	1.03	205	84	
14:30	1.28	140	84	
14:31	1.30		168	Increase Injection Rate
14:35	1.37	180	168	
14:45	1.53	183	168	
15:00	1.78	185	168	
15:01	1.80		252	Increase Injection Rate
15:05	1.87	170	252	
15:10	1.95	175	252	
15:15	2.03	170	252	
15:20	2.12	168	252	
15:25	2.20	152	252	
15:30	2.28	154	252	
15:31	2.30		336	Increase Injection Rate
15:35	2.37	137	336	
15:40	2.45	144	336	
15:45	2.53	139	336	
15:50	2.62	135	336	
15:55	2.70	124	336	
16:00	2.78	116	336	
16:05	2.87	109	336	
16:06	2.88		420	Increase Injection Rate
16:10	2.95	120	420	
16:15	3.03	115	420	
16:25	3.20	111	420	
16:26	3.22		504	Increase Injection Rate
16:30	3.28	122	504	
16:33	3.33	120	504	
16:34	3.35		420	Reduce Injection Rate
16:40	3.45	95	420	
16:50	3.62	90	420	
16:54			420	
16:55	3.70		378	Reduce Injection Rate (to maximum sustainable)
17:00	3.78	66	378	
17:10	3.95	59	378	Run Survey #1 (Amerada PTS)
17:20	4.12	40	378	
17:30	4.28	55	378	
17:40	4.45	56	378	
17:50	4.62	50	378	
18:00	4.78	48	378	
18:20	5.12	42	378	
18:30	5.28	37	378	
18:40	5.45	33	378	
18:50	5.62	19	378	
19:00	5.78	13	378	
19:10	5.95	10	378	
19:20	6.12	5	378	
19:30	6.28	0	378	
21:00	7.78	0	378	Run Survey #2 (Amerada PTS)
22:09	8.93	0	378	
22:10	8.95	0	0	Shut off Injection

Depth feet	Run#1 1/23/91 Pressure psig	Run#1 1/23/91 Temperature F	Run#2 1/23/91 Pressure psig	Run#2 1/23/91 Temperature F
100	82	87.5	13.5	95.1
1000	454	89.9	374	97.6
2000	876	91.1	796	99.4
3000	1306	93.3	1215	101.6
3700	1598	99.7	1507	105.9
3800	1640	100.7		
4500	1932	108.9	1837	115.1
5000	2135	115.7	2038	122.1
5500	2341	123.6	2241	129.4
6000	2544	131.5	2452	135.8
6500	2745	139.5	2632	143.1
6725			2739	145.5
6800	2862	145.2	2771	146.4

Elapsed Time minutes	Elapsed Time hours	Injection/Falloff From 2210:1/23/91 Pressure @ 6800' psig	Pressure Change psi	Injection/Falloff From 2210:1/23/91 Temperature @ 6800' F
0	0.00	2771	0	146.4
3	0.05	2659	112	
5	0.08	2612	159	150.6
7	0.12	2573	198	
10	0.17	2534	237	171.6
12	0.20	2519	252	
15	0.25	2503	268	213.4
20	0.33	2483	288	256.6
30	0.50	2462	309	282
40	0.67	2450	321	300.5
60	1.00	2437	334	315.3
120	2.00	2417	354	328.3
180	3.00	2407	364	339.5
240	4.00	2403	368	349
360	6.00	2399	372	357.3
540	9.00	2395	376	359
5754*	95.90	2437	334	511.8
7194*	119.90	2444	327	527.7
8640*	144.00	2444	327	536

* Data @ 6800' from subsequent static surveys